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WILL OF THE WIND: INNOVATING AN ARDUINO-BASED SMART GIROMILL EQUIPPED WITH A WIND SPEED INDICATOR AND ALARM SYSTEM FOR MAASIM FISHERFOLKS

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ABSTRACT

The innovative Arduino-Based Smart Giromill, equipped with wind speed indicator, and warning system, holds promise in renewable energy solutions. It enhances monitoring and safety in wind energy use while addressing technical and socio-economic challenges for decarbonized electricity. The study informs renewable energy policies, fosters innovation ecosystems, and supports sustainable development goals. It was conducted in the school year *2023-2024* at Maasim Municipality for the fisherfolks within the locality for their safety against the possible occurrence of typhoons and energy consumption during offshore fishing. Moreover, to confirm the functionality of the innovative Arduino-Based Smart Giromill, it underwent a series of tests for its mechanical design, electrical design, windspeed sensing capability, and alarm system capabilities. The results of the tests revealed that the Arduino-Based Smart Giromill is *100*% functional in all of its aspects evaluated. Furthermore, it was also found that it can only endure its capacity to detect wind speed up to *80* km/h based on the three (*3*) trials done from the *60* km/h speed test. This wind speed results further give the equivalent of *7* to *9* knots with a corresponding Beaufort Wind Force Scale number *3*, indicating a light breeze sea condition. Hence, it is suggested that future researchers may use this study as a blueprint for

developing and optimizing similar monitoring systems, advancing renewable energy technology for a greener future.

Innovation, Arduino-Based Smart Giromill, Functionality, Mechanical Design, Electrical Design, Windspeed Sensing Capability, Alarm System Capabilities, Wind Speed Scale Test

INTRODUCTION

Fishermen rely on fishing as their primary source of income, collecting a variety of aquatic creatures for sale or consumption. Their livelihood is inextricably linked to weather conditions, fishing laws, and the health of maritime ecosystems. Wind-water interaction refers to complicated processes that occur within the earth's atmosphere and hydrosphere, involving the exchange of energy, momentum, and properties between surface water bodies and the atmosphere (Janssen, 2004).

When it comes to wind and sea, fishermen prioritize safety and production. Windy waters provide a risk to fishing activities, while severe gusts can induce drifting off course or capsizing, reducing fishing success. Furthermore, contemporary turbines exploit wind's kinetic energy to generate mechanical power that can be used for a variety of applications, including electricity generation (Uddin, Islam, Nadim, & Afjal, 2013).

Moreover, electricity is necessary for fishing activities, and powering equipment such as vessel lights and communication devices. Using wind speed indicators and alarm systems improves maritime safety, optimizes fishing operations by giving real-time notifications, and facilitates effective action planning (Muir, 2015).

Thus, the researchers were pressed to innovate solutions like the Arduino-Based Smart Giromill that strives to answer fishermen's energy concerns while also providing a safe journey with features such as a wind speed meter and an emergency warning system. These improvements not only improve current methods, but also pave the door for ethical and sustainable fishing operations.

Statement of the Problem

This study innovated an Arduino-based Smart Giromill, in light of the aforementioned goal, the researchers investigated the following queries:

1.) What were the innovations made with the Arduino-based Smart Giromill from the previous study conducted by Carriaga et al. (2020)?

2.) How functional was the innovated Arduino-based Smart Giromill in terms of:

2.1 Mechanical Design;

2.2 Electrical Design;

2.3 Windspeed Sensing Capability;

2.4 Wind Speed Scale Test; and

2.5 Alarm System Capabilities?

Solution/Innovation

This project innovated an Arduino-based Smart Giromill that ensures the safety of Maasim fisherfolks while trying to make a living or for their daily consumption. With its safety features, the fishermen will be able to monitor the speed of the wind and will be alarmed once the wind exceeds the normal speed.

Features and Specifications

- **Arduino-Based:** The Smart Giromill system is built on Arduino technology, which is well-known for its adaptability and accessibility.
- **Smart Giromill:** Incorporates a Giromill design, which is a sort of vertical-axis wind turbine optimized for efficiency and dependability in wind energy harvesting.
- **Wind Speed Indicator:** Features include a real-time wind speed indicator, which provides exact assessments of wind conditions to help fishermen navigate safely and efficiently.
- **Alarm System:** Includes an alarm system that is activated by predefined wind speed thresholds, alerting fishermen to potentially hazardous situations and lowering the likelihood of accidents at sea.
- **Safety Enhancement**: Focuses on boosting safety at sea by giving early notices and alarms based on current wind speed data, therefore lowering the likelihood of accidents or crises.
- **Energy Generation**: Using wind energy to create electricity provides a sustainable and renewable power supply for onboard equipment and systems.
- **User-Friendly Interface**: Designed with a user-friendly interface, fishermen can easily control and interpret the system's data and alarms.
- **Resource Conservation**: Supports resource conservation initiatives by encouraging the use of renewable energy and making informed decisions to reduce environmental effects.
- **Innovation for Community Benefit**: Developed with the specific demands and concerns of fishermen in mind, the goal is to improve their safety, efficiency, and overall livelihood through technological innovation.

Materials and Methods

In this study, the researchers employed an adapted but modified protocol from Carriaga, et al. (2020). Also, the researchers utilized the quantitative method, particularly the true experimental design in testing the mechanical design, electrical design, wind-sensing capability, and the alarm system of the innovated Smart Giromill. According to Pubrica-Academy (2022), experimental research is a sort of scientific inquiry in which one or more independent variables are altered and then applied to one or more dependent variables to determine how they affect the latter. The effect of independent variables on dependent variables is commonly seen and recorded throughout time, allowing researchers to make a convincing conclusion regarding the relationship between these two types of variables. Furthermore, experimental research designs, which are most commonly connected with laboratory test methods, involve collecting quantitative data and statistically analyzing it during the study process.

Materials Used:

The Smart Giromill was made up of the following materials:

- **Motorcycle batteries:** Utilized to be the storage of electric current.
- **Diode:** Transforms the AC into DC.
- **Bolts and nuts:** Fasteners are used together to join components by threading the bolt through one component and securing it with the nut.
- **Hub:** Utilized to hold the propeller and the bracket in place.
- **Brackets:** Used to join the PVC (propeller) to the hub.
- **Rod-shaped steel:** Acts as a tower of Smart Giromill.
- **Wire:** A thin metal strand used for conducting electricity.
- **Charge controller:** Controls the current flowing into and out of the battery to avoid overcharging and over-discharging.
- **Capacitor:** Stores voltages from the AC motor before sending it to the charge controller.
- **Cups:** Utilized as an alternative anemometer cup used to measure wind speed.
- ***16x2* LCD screen:** Provides a user interface for monitoring wind speed and displays data in a human-readable format, including wind speed and other pertinent information.
- **Arduino Uno:** Serves as the main microcontroller unit in charge of reading data from the anemometer, transmitting output to the LCD panel, operating the software, and managing the complete system.
- **Breadboard:** Facilitates the organization and distribution of power and signals among components and offers a platform for testing and developing circuits without the need for soldering.
- **I2C Adapter:** An interface module that translates signals from the Arduino into signals that are compatible with the LCD monitor and enables communication between the Arduino and the display using the I2C protocol.
- **Jumper wires:** Attach different parts, making electrical connections between the Adafruit Anemometer, LCD, and Arduino.
- **The Polyvinyl Chloride (PVC) pipe:** is attached to the bracket and functions as the Smart Giromill's blade or propeller.
- **Active buzzer:** Acts as the alarm system when the detected wind speed exceeds the normal level.

- **LED lights:** Similar to the active buzzer it also acts as the alarm system when the detected wind speed exceeds the normal level.
- ***6*V DC motor:** Utilized as the main component used to measure wind speed through rotation per minute (RPM).
- **Scrap AC motor:** Utilized as the main component used to generate electricity.
- **Non-Sag Epoxy:** Used as an adhesive for the AC motor to be attached to the PVC.
- **Flexible Hose:** Utilized to protect wires from potential bad conditions brought by the weather.
- **Cable tie:** Used as adhesives for electrical wiring.
- **Electrical tape:** Used to put insulations to prevent short circuits if wires come in contact.
- **Soldering lead:** Utilized to connect the copper wires.

Tools Used:

The tools used in making the Smart Giromill are the following:

- **Pliers:** Used in cutting wires and twisting wire insulations.
- **Screwdrivers:** Tools used to tighten and loosen screws.
- **Arduino USB cable:** Connects the Arduino board to a computer for programming and power supply.
- **Multi-Tester:** Utilized to measure both the current flow in the system and the voltage produced by the Giromill.

Equipment Used:

These are the following equipment utilized in assembling the Smart Giromill:

- **Laptop:** Used as the equipment in programming the Arduino Uno.
- **Table:** Serves as the surface where the experiment is conducted.
- **Soldering iron:** Utilized to melt soldering lead and join together electronic components or wires.

Paraphernalia Used:

The researchers employed the following paraphernalia for their Smart Giromill:

- **Insulated rubber gloves:** Prevent shocks and burns.
- **Electrical Goggles:** Used to protect the researchers' eyes while conducting the innovation.

RESULTS AND DISCUSSION

This section explains the results achieved after a series of tests was made to determine the functionality of the innovative Arduino-based Smart Giromill.

Innovation Development Process of Arduino-Based Smart Giromill

In innovating an Arduino-based Smart Giromill, first, gather all the necessary materials for the Smart Giromill Project, including the *1* pc. Arduino Uno, *4* pcs. Giromill blades (PVC pipe), *2* pcs steel rods, *1* pc. Piezo active buzzer, *1* pc. *16x2* LCD monitor, jumper wires, *1* pc. capacitor, *4* pcs. diodes, flexible hose, bolts, nuts, hub, brackets, rod-shaped pole, wire, charge controller, LED lights, *6*V DC motor, scrap AC motor, non-sag epoxy, cable tie, electrical tape, soldering lead, *4* pcs. cups and a breadboard for organizing the connections. Secondly, Construct the Giromill structure by ensuring that the blades that were attached to the bracket are securely mounted to the hub to efficiently capture wind. Third, using non-sag epoxy, attach the hub to the rotor shaft (Scrap AC motor). Fourth, attach the diode to the wire to convert AC to DC and then fasten the capacitor to avoid current overload. Fifth, connect the wire to the charge controller's solar port and connect a wire from the battery port to the motorcycle battery. Next, the researchers proceeded in installing the wind speed sensor by assembling the following components. *4* pcs. cups, steel rod, and the 6V DC motor. The researchers then connected one terminal of the *6*V DC motor (negative wire) to the ground (GND), and the other terminal (positive wire) to the analog pin (A0) of the Arduino Uno.

Moreover, the researchers used a Breadboard as a platform for circuits in the wiring. The researchers connected one end of the jumper wire to the ground (GND) of the Arduino Uno and the other end to the negative power rail of the Breadboard. Another jumper wire was connected to the *5*V of the Arduino Uno to the positive power rail of the Breadboard. Furthermore, for the *16*x*2* LCD, the researchers used the I2C monitor to connect it to the Arduino Uno with pins GND, VCC, SDA, and SCL. The GND was connected to the negative power rail of the Breadboard powered by the GND of the Arduino while the VCC was connected to the positive power rail of the Breadboard powered by the *5*V of the Arduino, then the pins SDA and SCL were connected to the analog pins (A*4* & A*5*) of the Arduino Uno respectively.

Next, for the piezo active buzzer, the researchers used a current-limiting resistor of (*220* ohms) with the other terminal to the negative power rail and the other terminal to the powered terminal strip of the Breadboard. The negative wire (black) of the buzzer was connected to the other end of the resistor then another jumper wire was used to power up the terminal trail of the Breadboard with the digital pin (*12*) of the Arduino Uno. The positive wire (red) of the buzzer was connected to the pin *12* powered terminal trail of the Breadboard. Moreover, for the LED light, the researchers used another current-limiting resistor of (*220* ohms) with the other end connected to the negative power rail and the other end to the powered terminal strip. The researchers then connected the negative wire (black) of the LED light to the other end of the resistor while the positive wire (red) was connected to the pin 12 powered terminal trail of the Breadboard.

Furthermore, the researchers wrote the Arduino code to handle sensor data, display wind speed on the LCD monitor, and trigger the piezo active buzzer based on predefined thresholds. The researchers then utilized appropriate libraries for interfacing with the wind speed sensor, and LCD monitor. Then, the researchers uploaded the code to the Arduino Uno using the Arduino IDE. After that, the researchers tested the system by manually spinning the giromill blades to simulate wind, monitored the LCD for wind speed readings, and listened to the piezo active buzzer alarm when thresholds were reached. Finally, the researchers tested the functionality of the innovative project to answer the scientific problems present in the study.

Functionality of Arduino-Based Smart Giromill

This study evaluated the functionality of the innovation made, i.e., Arduino-based Smart Giromill with respect to its mechanical design, electrical design, windspeed sensing capability, and alarm system capabilities. To achieve the results of these tests, a series of trials were performed using a checklist. Tables *1-4* show the complete results.

Table 1. Mechanical Design Testing Results

MECHANICAL DESIGN INDICATORS	Trial 1		Trial 2		Trial 3	
	Yes	No	Yes	No	Yes	No
Are the rotor blades stable without wobbling or imbalance?	✓		✓		✓	
Are the blades free from cracks, deformations, or signs of wear?	✓		✓		✓	
Is the rotor shaft properly aligned with the blades?	✓		✓		✓	
Is the tower structure sturdy and able to support the Giromill in various wind conditions?	✓		✓		✓	
Is the Arduino code properly written and functioning as intended?	✓		✓		✓	
Has the mechanical design been tested for long-term durability under typical wind conditions?	✓		✓		✓	

The results show that the prototype Arduino-based Smart Giromill is ***100%* functional** in terms of its mechanical design as evidenced by the *6/6* **YES**. This implies that the rotor blades are stable without wobbling or imbalance; the blades are free from cracks, deformations, or signs of wear; the rotor shaft is properly aligned with the blades; the tower structure is sturdy and able to support the Giromill in various wind conditions; the Arduino code is properly written and functioning as intended, and the mechanical design has been tested for long-term durability under typical wind conditions.

This indicates that the Arduino-based Smart Giromill prototype is mechanically sound, reliable, and ready for further development and potential market introduction, with significant positive implications for renewable energy solutions, economic feasibility, and environmental sustainability. Developing an Arduino-based Smart Giromill for fishermen provides numerous benefits, including reliable and sustainable power, cost savings, improved operational efficiency, environmental conservation, economic empowerment, technological advancement, enhanced safety, and positive community impact. These advantages make it a valuable innovation for the fishing industry and beyond (Mubarok, 2018).

Table 2. Electrical Design Testing Results

ELECTRICAL DESIGN INDICATORS	Trial 1		Trial 2		Trial 3	
	Yes	No	Yes	No	Yes	No
Does the windmill produce sufficient voltage output?	✓		✓		✓	
Is the wind speed sensor interfaced correctly with the Arduino board?	✓		✓		✓	
Are the buzzer and LED effectively integrated with the Arduino for alarm activation?	✓		✓		✓	
Is the power supply stable and sufficient to power the entire system?	✓		✓		✓	
Are voltage regulators or stabilizers used to ensure consistent voltage levels?	✓		✓		✓	
Are wires properly insulated and routed to minimize interference and risk of short circuits?	✓		✓		✓	
Does the Arduino board power up and function correctly?	✓		✓		✓	

The table above shows that the electrical or electronic design of the prototype Smart Giromill is ***100% functional***, as all of the electronic components that are present in the innovation are working properly according to the command. This means that the windmill produces sufficient voltage output; the wind speed sensor interfaced correctly with the Arduino board; the buzzer and LED are effectively integrated with the Arduino for alarm activation; the power supply is stable and sufficient to power the entire system; the voltage regulators or stabilizers are used to ensure consistent voltage levels; the wires are properly insulated and routed to minimize interference and risk of short circuits, and the Arduino board powers up and functions correctly.

This implies that the *100%* functionality of the electrical and electronic design of the Smart Giromill prototype is close to being market-ready. This can accelerate the product development cycle and instill confidence in potential investors and consumers. Demonstrating a fully functional electronic design gives the Smart Giromill a competitive edge in the renewable energy market, highlighting its robustness and reliability. Also, the success of electronic design in the prototype suggests that the system can be scaled up or adapted for larger or different applications, potentially broadening its use cases.

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WINDSPEED-SENSING CAPABILITY INDICATORS	Trial 1		Trial 2		Trial 3	
	Yes	No	Yes	No	Yes	No
Does the wind speed sensor provide accurate readings under varying wind conditions?	✓		✓		✓	
Can the threshold for triggering the alarm system be adjusted to accommodate different wind speed requirements?	✓		✓		✓	
Is the wind sensing capability reliable and consistent over time?	✓		✓		✓	
Is the wind speed sensor effectively integrated with the alarm system to trigger alerts when necessary?	✓		✓		✓	
Has the wind sensing capability been tested in different environmental conditions (e.g., rain, dust) to ensure reliability?	✓		✓		✓	
Does the speed of the boat affect the ability of the wind turbine to produce electricity?	✓		✓		✓	
Does the wind speed sensor interface smoothly with the Arduino-based control system?	✓		✓		✓	

Table 3. Windspeed Sensing Capability Testing Results

Table indicates that the prototype Smart Giromill is ***100%* functional** as demonstrated by *7/7* **YES** results across all trials performed. This means that the wind speed sensor provides accurate readings under varying wind conditions; the threshold for triggering the alarm system can be adjusted to accommodate different wind speed requirements; the wind sensing capability is reliable and consistent over time; the wind speed sensor is effectively integrated with the alarm system to trigger alerts when necessary; the wind sensing capability has been tested in different environmental conditions (e.g., rain, dust) to ensure reliability; the speed of the boat affects the ability of the wind turbine to produce electricity, and the wind speed sensor interfaces smoothly with the Arduino-based control system.

The results suggest that the wind speed sensor's accuracy under varying wind conditions ensures the Smart Giromill operates optimally, maximizing energy production and system efficiency. Its reliable and consistent wind sensing capability over time implies that the system can be depended upon for long-term use without significant degradation in performance. Moreover, its ability to adjust the alarm system's thresholds for different wind speeds allows for customization based on specific operational needs or safety requirements, enhancing the system's versatility. Also, testing in diverse environmental conditions (e.g., rain, dust) confirms the system's robustness and ability to maintain functionality in real-world scenarios, crucial for deployment in various geographic locations (McConnel, 2018).

Simply put, the *100%* functionality of the Smart Giromill prototype has wide-ranging implications, including reliability, adaptability, seamless integration, operational impact, practical applications, market potential, environmental and economic benefits, and future development opportunities. These results mean that the Smart Giromill is a viable and valuable solution for renewable energy generation in maritime contexts.

Table 4. Wind Speed Scale Test Results of the Innovated Arduino-Based Smart Giromill

SPEED TEST	TRIALS	VOLTAGE GENERATED	WIND SPEED (in m/s)	WIND SPEED (in km/h)	EQUIVALENT KNOTS	Beaufort Number	Sea Conditions
60 km/h	Trial 1	0.25	3.35	12.060	7	3	Light Breeze
	Trial 2	0.26	3.48	12.528	7	3	Light Breeze
	Trial 3	0.27	3.61	12.996	7	3	Light Breeze
80 km/h	Trial 1	0.33	4.42	15.912	9	3	Light Breeze
	Trial 2	0.34	4.55	16.380	9	3	Light Breeze
	Trial 3	0.35	4.69	16.882	9	3	Light Breeze

Table *4* shows the results of the testing performed to test the wind scale that the innovative Arduino-based Smart Giromill was able to endure optimally. Based on the findings, it can be gleaned that the Smart Giromill can only endure its capacity to detect wind speed up to *80* km/h based on the three (*3*) trials done from the *60* km/h speed test. This wind speed results further give the equivalent of *7* to *9* knots with a corresponding Beaufort Wind Force Scale number *3*, indicating a light breeze sea condition. Moreover, the table indicates that the speed of vessel is directly proportional to the voltage generated. Meaning, as the speed of the vessel increases, the voltage generated from the wind speed also increases.

These results imply that the Smart Giromill's capacity to detect wind speeds up to *80* km/h suggests that it is suitable for environments where wind speeds typically do not exceed this limit. This encompasses a range of light to moderate breezes as indicated by the Beaufort Wind Force Scale. Beyond *80* km/h, the system may not reliably detect wind speed or might suffer from mechanical or electronic strain, indicating a need for enhancements if it is to be used in harsher wind conditions.

Furthermore, The Smart Giromill is well-suited for regions experiencing light to moderate wind conditions, such as coastal areas with stable wind patterns. This aligns with the indicated Beaufort

Wind Force Scale number of *3*, which corresponds to a light breeze at sea. Industries and activities that operate within these wind conditions, such as small-scale fishing, recreational boating, or coastal monitoring, can benefit from the Giromill's capabilities.

Table 5. Alarm System Testing Results

ALARM SYSTEM INDICATORS	Trial 1		Trial 2		Trial 3	
	Yes	No	Yes	No	Yes	No
Does the alarm system respond promptly when wind speeds exceed the preset threshold?	✓		✓		✓	
Is the alarm system integrated with the Arduino-based Smart Giromill?	✓		✓		✓	
Does the alarm system activate based on predefined wind speed thresholds?	✓		✓		✓	
Does the alarm system provide real-time notifications?	✓		✓		✓	
Can the alarm system be easily reset after activation?	✓		✓		✓	
Does the alarm system include audible alerts?	✓		✓		✓	
Does the alarm system include visual indicators (e.g., LED lights)?	✓		✓		✓	
Can the alarm system differentiate between varying levels of wind speed?	✓		✓		✓	
Is the alarm system designed to enhance safety for fisherfolks at sea?	✓		✓		✓	
Is the alarm system user-friendly and easy to operate?	✓		✓		✓	
Does the alarm system contribute to minimizing the risk of accidents or emergencies?	✓		✓		✓	

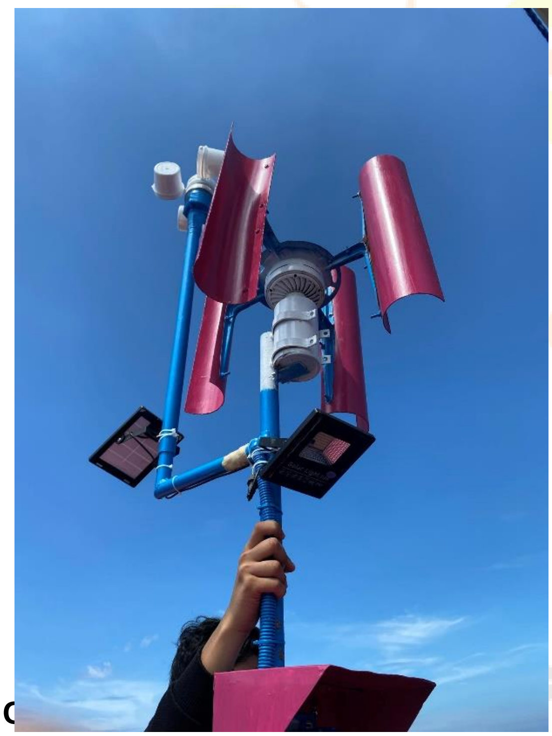
The table exemplifies that the innovative Arduino-based Smart Giromill is ***100%* functional** in terms of its alarm system. This means that the alarm system responds promptly when wind speeds exceed the preset threshold. The alarm system is integrated with the Arduino-based Smart Giromill; the alarm system activates based on predefined wind speed thresholds; the alarm system provides real-time notifications; the alarm system can be easily reset after activation; the alarm system includes audible alerts; the alarm system includes visual indicators (e.g., LED lights); the alarm system differentiates between varying levels of wind speed; the alarm system is designed to enhance safety for fisherfolks at sea; the alarm system is user-friendly and easy to operate, and the alarm system contributes to minimizing the risk of accidents or emergencies.

Given these results, the alarm system's ability to respond promptly when wind speeds exceed preset thresholds enhances safety by providing timely warnings to fisherfolk, allowing them to take precautionary measures. By differentiating between varying levels of wind speed and providing real-time notifications, the system minimizes the risk of accidents or emergencies caused by sudden changes in wind conditions. Also, the system's ease of use ensures that fisherfolk can quickly understand and operate the alarm, reducing the learning curve and enhancing overall efficiency in responding to wind conditions. Moreover, the integration with the Arduino-based Smart Giromill ensures that the alarm system works cohesively with the overall system, enhancing reliability and functionality.

Benefits

The Arduino-Based Smart Giromill, equipped with wind speed indicator, and warning system, holds promise in renewable energy solutions. It enhances monitoring and safety in wind energy use while addressing technical and socio-economic challenges for decarbonized electricity. The study informs renewable energy policies, fosters innovation ecosystems, and supports sustainable development goals. It also provides valuable learning opportunities for STEM students, aligning technical principles with sustainability goals. For fishermen, the technology enhances efficiency, catch rates, and safety at sea, leveraging natural wind energy for sustainable electricity. Real-time data on environmental factors enables informed decision-making. Future researchers can use this study as a blueprint for developing and optimizing similar monitoring systems, advancing renewable energy technology for a greener future.

Visuals



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The Arduino-Based Smart Giromill, equipped with a wind speed indicator, and warning system, provides a sustainable and cost-effective energy source that can empower coastal and fishing communities, improving economic stability and quality of life. The successful deployment and operation of the Smart Giromill may serve as a practical example for educational programs focused on renewable energy and sustainable practices. Furthermore, its comprehensive functionality, combined with its specific wind endurance capabilities, has broad implications for reliability, safety, market focus, economic viability, design enhancement, research opportunities, environmental impact, and community benefits. These results underscore the system's potential as a valuable renewable energy solution for specific environmental conditions.

Future Development

1. As this study progresses the researchers failed to test the durability of the innovated Smart Giromill under various weather conditions.
2. It is also recommended that future researchers may use a standard anemometer to prevent complexities in coding the calibrations.
3. The future innovators of this project may also incorporate solar panels to utilize both wind and solar energy to produce electricity.
4. To improve the safety of the fishermen, future researchers may consider incorporating tracking devices so that locating the fishing vessel will be much easier if unfortunate things happen.

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