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Powering a Microcontroller with Ambient Energy to Track the Local Weather

***Abstract*– This paper presents the comprehensive process of designing, developing, and testing ambient energy sources, particularly wind and wave energy, to power a microcontroller for recording and transmitting local meteorological data in challenging environments. From wave and wind energy to the utilization of the point absorber method and following the principles of mechanical vibrations, each one contributes to a unique opportunity for energy-efficient utilization. The integration of sensors with the microcontroller, programmed using Arduino IDE software, enables real-time monitoring of weather conditions. Additionally, a mobile application facilitates data dissemination and accessibility, allowing prompt access to recorded data. Incorporating a Bluetooth module ensures seamless data transmission, while an SD card serves as reliable data storage. A buoy is affixed to a large plate to evaluate wave energy efficacy, providing a practical testing environment. Through these efforts, this project aims to develop a maintenance-free, roaming monitoring solution suitable for remote oceanic environments, advancing sustainable energy. Integrating ambient energy into everyday technology, particularly microcontrollers, demonstrates its viability in powering systems reliably. Recording and transmitting local meteorological data is the anticipated outcome in a challenging setting.**

***Keywords* – Ambient energy, microcontroller, Arduino IDE, sustainability.**

I. Introduction

In an era where sustainability and renewable energy are paramount, the exploration and utilization of ambient energy sources have gained significant attention. There are a variety of sources of ambient energy, which is the energy present in our environment. To better understand the concept, this power source can be divided into two categories. The first category refers to ambient energy that occurs naturally. The second category refers to power created by humans and their devices [1].

Naturally occurring ambient energy sources range from sunshine to mechanical forces like wind and waves. Sunlight, for instance, provides thermal energy that can be harnessed through solar panels, while the earth's core heat enables geothermal energy production. Wind energy, another beneficial natural resource, has long been harnessed through wind turbines and mills, but innovations such as kite-powered systems and small-scale wind devices broaden the possibilities for wind energy usage.

Moreover, mechanical vibrations, often overlooked, present another avenue for energy extraction. Piezoelectric energy harvesters can transform ambient vibrations into electrical energy, demonstrating that even little motions in the environment can contribute to power generation [2].

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As a natural phenomenon, ocean waves are a powerful and vast energy source. Early inventions like the whistling buoy laid the groundwork for wave energy utilization, with modern systems like oscillating water columns, attenuators, and overtopping devices offering sophisticated means of harnessing this renewable resource [3] .

Furthermore, the integration of ambient energy into everyday technology, such as microcontrollers, demonstrates its potential for providing sustainable power to critical systems. However, challenges persist, such as the intermittent of specific ambient energy sources like solar power.

In addressing these difficulties, developments like rechargeable batteries act as a bridge, allowing for uninterrupted operation even during days with low ambient energy availability.

Overall, exploring and developing ambient energy sources is an important step toward creating a sustainable future. By harnessing the power inherent in our environment, we can reduce reliance on finite resources and mitigate environmental impacts, paving the way for a cleaner and more resilient energy landscape.

II. Need Statement

There are many places on the earth's surface where power sources cannot effectively supply energy to several operating devices. The use of ambient energy near these places is beneficial whenever possible. The number of people without access to electricity increased for the first time in decades, hitting 760 million people worldwide. Of these, 18 million people in Latin America lack access to electricity, making it difficult to refrigerate food or use other services that improve their quality of life [4]. There are many locations with little to no access to energy, so this project aims to use renewable energy there. The intention to provide energy through electric current at these locations faces various difficulties due to the expensive and extensive maintenance required to supply power for a prolonged period. With the ocean covering approximately two-thirds of the earth's surface, ambient energy, such as wave energy, can provide energy at remote and inaccessible locations through free-roaming devices that can run without maintenance for long periods.

Furthermore, wind energy will be studied as an alternative for powering devices due to its sustainability and abundance of power, which does not emit greenhouse gases or require any combustion procedures. This project aims to study, analyze, and report a smaller-scale behavior of ambient energy using ambient energy to power a microcontroller A microcontroller and a sensor are coded using the Arduino IDE software, and an application is created in FlutterFlow. This process involves meticulously programming the microcontroller with specific functionalities through the Arduino IDE, a popular platform for writing and uploading code to Arduino boards. Meanwhile, sensor integration enables the device to interact with its environment by receiving inputs the programmed microcontroller can process. Following the successful coding and integration in the Arduino environment, the next step focuses on developing a user-friendly application. This application, built within the FlutterFlow environment, allows an intuitive interface to interact with the hardware setup, facilitating seamless user-to-device interaction. Through this implementation, the microcontroller will be capable of sensing the temperature and humidity of the air around its body. Powering households and essential devices is envisioned on a larger scale for the project.

A. Societal Impact

This project aims to accomplish three primary goals. Firstly, to enhance individuals' quality of life; secondly, to support the development of Latin America; and thirdly, to contribute to meeting the worldwide energy demand. Renewable energy sources such as wind and wave power can significantly transform people's lives by educating and empowering communities across the globe but more importantly, by it's potential to bring electricity to remote areas, and vastly improve their access to vital services, such as clean water, health care, and education.

Ambient energy can be useful to address energy accessibility challenges in underserved regions across the continent, facilitating socio-economic development. Additionally, the deployment of ambient energy technologies creates job opportunities and stimulates economic growth in the region.

B. Environmental Impact

The project strives to facilitate the adoption of ambient energy technologies while raising awareness about the benefits of renewable energy sources and encouraging sustainable practices in Science, Technology, Engineering, and Mathematics (STEM) fields among students. Using wind and wave energy reduces reliance on finite fossil fuels, promoting environmental sustainability and ecosystem preservation. The transition from fossil fuel-based power plants to renewable energy sources is critical for addressing climate change and achieving net zero carbon emissions [5]. The impact of ambient energy is becoming more significant in Latin America. Embracing new energy systems proposes a proactive approach to dealing with natural disasters. In regions susceptible to natural disasters such as hurricanes or earthquakes, decentralized energy systems powered by wind and wave energy provide a reliable energy source when traditional power infrastructure fails, allowing for a faster recovery and preparation for future disasters. The resilience provided by decentralized energy systems is invaluable and holds great promise for Latin America, offering a pathway towards a more sustainable and resilient energy future. Between 2000 and 2022, 1,534 disasters harmed 190 million people in Latin America and the Caribbean, making it the second most disaster-prone region globally[6]. Natural resource-based power has the potential to reduce environmental consequences caused by prolonged and excessive use of nonrenewable energy. Reducing the use of non-renewable energy contributes to the fight against climate change and reduces air pollution, which improves public health and protects the environment. The educational advancements that can be achieved by utilizing new technologies inspire interest in STEM fields and contribute to mitigating climate change effects, environmental preservation, and public health improvement.

III. MARKET RESEARCH

The project budget may vary depending on the components used and the method used for harvesting ambient energy. Most monitoring systems are based on local energy systems rather than ambient energy. This project solves this situation with a technique of collecting ambient energy called point absorber. Due to the market's low availability of point absorbers, the team's point absorber was personalized to meet the design requirements. The point absorber was customized using a buoy and a heave plate design consisting of an aluminum disk, an acrylic tube, and magnets. The cost of measuring the pH levels and the local weather varies depending on the sensors used. Considering the project's target audience, low-cost sensors were used to calculate the environment. Considering the efficiency of the sensors, the project's total cost was about USD 450. This includes all sensors and components used to build the point absorber.

IV. AUDIENCE

This project's target audience includes communities globally confronting a lack of electricity, particularly the 18 million people in Latin America who do not have access to power [4]. The project aims to provide sustainable solutions to places without stable energy by studying and utilizing ambient energy sources such as wave and wind power. Researchers, engineers, and entrepreneurs interested in renewable energy innovations and microcontroller applications will benefit from the project's analysis, design, and implementation of ambient energy systems. The project's findings will also help governments and non-governmental organizations (NGOs) work to address energy access challenges and promote sustainable development in distant and inaccessible regions. Finally, the initiative intends to provide communities with the tools they need to improve their quality of life by providing reliable, renewable energy sources to power vital equipment and families on a broad scale.

V. ENGINEERING REQUIREMENTS

The project must meet the following requirements to accomplish its purpose according to goals and desired results of the team.

1) Ambient Energy Harvesting Devices: Create and implement effective systems for collecting ambient energy from waves, wind, and mechanical vibrations. These devices should generate enough electricity to provide energy to households and critical devices in distant and inaccessible areas.

2) *Microcontroller and Sensor integration:* Combine microcontrollers and sensors to efficiently capture and use the gathered ambient energy. Create coding methods utilizing platforms like the Arduino IDE that allow the microcontroller to detect and monitor environmental elements such as temperature and humidity.

3) *Power Management System:* Use power management platforms to efficiently store and distribute harvested energy. This includes developing rechargeable battery systems that can store energy during high environmental energy availability while providing energy during low-power terms.

4) *Testing and optimization:* Extensive testing and optimization of ambient renewable energy devices, microcontroller systems, and sensor integration is required to ensure dependable and efficient operation in various environments. Iterate on the development and execution to improve performance and address any issues or constraints during testing.

VI. Budget

The project's overall cost includes the sensors and other components used to collect energy for a microcontroller, which are listed in Table 1.

TABLE 1
COMPONENT PRICE LIST

Component	Qty.	Subtotal USD
Soldering Iron Kit	1	21.99
PLA 3D Printer Filament	1	24.99
Wind Generator Kit	1	9.99
ATmega328P Seeeduino Embedded Evaluation Board	1	9.12
AHT20 Industrial Temp & humidity sensor	1	6.40
Bluetooth Module	1	33.00
SanDisk Ultra microSD car (128GB)	1	18.99
Materials to build the wave energy collector		
Enamelled Copper Wire	1	11.45
Gorilla Waterproof Patch & Seal Spray, Clear, 14 Ounces	1	14.94
Neodymium Magnets	1	10.97
Linear Guide System	1	32.99
Aluminium Circle 12” ×1/4”	1	28.00
Acrylic Pipe OD 2 1/2×6ft×2 1/4 ID Clear 1/8 wall-Cut@3ft.lengths	1	51.50
Total		274.33

VII. Design Concept

When designing floating wave energy devices, the primary consideration is determining where the waterline will be located on the structure. The waterline, where buoyancy force meets gravitational force, is critical in mechanical design. As a result, the decision was made to combine two distinct methods of collecting wave energy. Following, an application was created to analyze the data and display the results.

A. *User Interface*

A customized application was needed to allow the prototype to transmit the collected data. The microcontroller used a Bluetooth module to communicate and save the collected data to an SD card. The Flutter Flow App creator was chosen to design and develop the app.

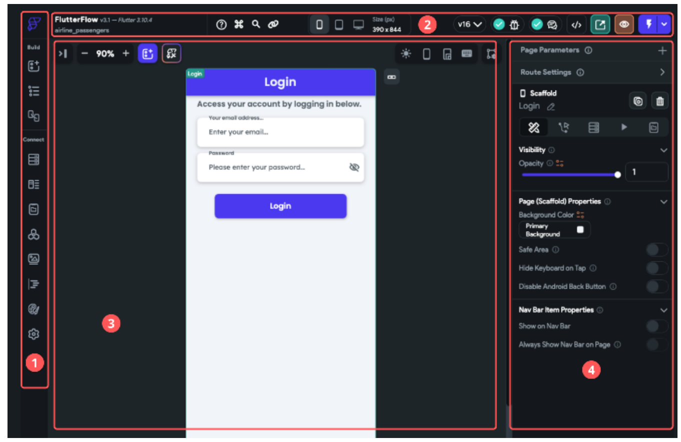

Fig. 1 FlutterFlow Web Display

B. *Mechanical Design*

Design of the Point absorbing wave energy collector method.

1) *Buoy Design:* The components establish the buoyancy, weight, and desired waterline position. It also has to be topologically a half-donut to allow the heave plate's tube to run through the center. The copper wire will be coiled around the central tube to neutralize the motion of the magnets within the heave plate tube and generate electricity.

2) *Heave Plate Design:* The heave plate subassembly must be buoyant to keep the tube's top free of approaching waves. It should also keep the heave plate far below the water surface to reduce the effects of wave-included bobbing motion. This tube will be suspended near the top magnets, aligning their poles vertically to generate electricity as they pass through a copper coil.

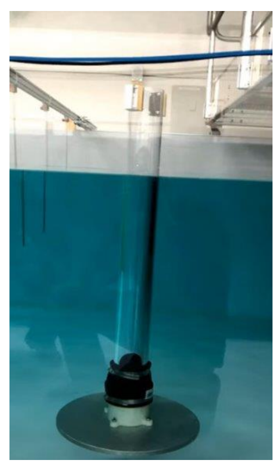

Fig. 2 Commercial Point Absorber Wave Energy Converter.

A linear guide system has been purchased to connect the two subassemblies, with the goal of preventing lateral motion. This step is critical because thinner central column walls may be required to facilitate interaction between coils and magnets on the heave plate.

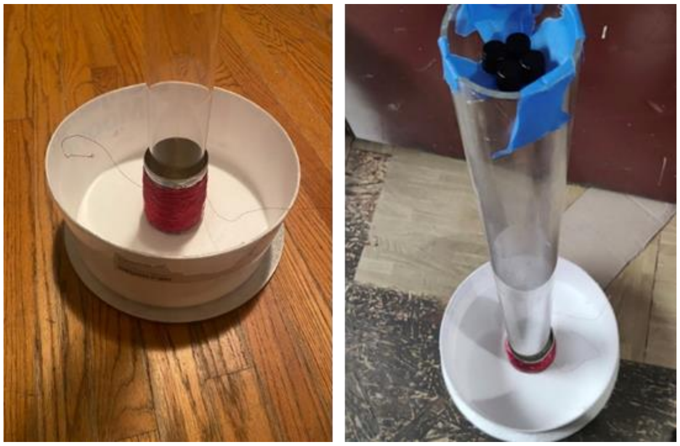

Fig. 3 Final design Prototype.

3) Wind Energy Collector: When the motors spin around, they produce an electric current. In contrast, when current is applied, the motors spin. This reciprocal relationship between motion and electricity is essential for optimal functioning. Example of the motor used is shown in Fig. 4.

Fig. 4 Motors used on the wind turbine.

When the wind generator kit arrived, it was identified that came with two different turbines. Their efficacy was evaluated concerning our energy sufficiency, with each's performance scrutinized to determine the best option. The example of the different types of blades used are in Fig. 5.

Fig. 5 The blades

The turbine was placed four inches from the fan and tested in three modes: high, medium, and low. Wires from the motor were connected to a multimeter for current and voltage measurements. Wattage was calculated based on Ohm's law. The total amount of energy generated was calculated by multiplying the average wattage by the duration of the experiment. The procedure above is shown in Fig. 3.

Fig. 6 Final wind collector prototype.

C. Coding

The program algorithm is outlined in the Fig. 7 below. The monitor communicates with the sensor via the inter-integrated Circuit (I2C), a synchronous serial communication bus. Based on the communication, the results are pasted onto the serial monitor. The code from Seeeduino Studios (Seeed studio) was used with the AHT20 sensor. As an open-source sensor, programming was more accessible.

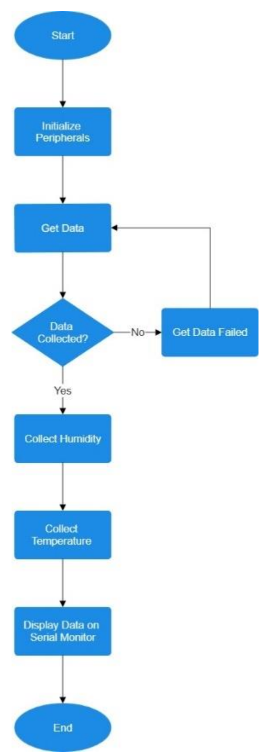

Fig. 7 Code flow chart.

Libraries such as "Wire.h" and "AHT20.h" were included to allow the microcontroller to communicate with the I2C device (AHT20 sensor). The AHT20 was initialized and declared in the void setup. In the void loop, a bool statement was created where data was retrieved from the sensor. If data is successfully acquired, the results are printed onto the serial monitor. If the data isn't successfully retrieved, the serial monitor will print an error message. Furthermore, these functions are implemented in the device, illustrated in Figure 8.

```
//
#include <Wire.h>
#include "AHT20.h"

AHT20 AHT;

void setup()
{
    Serial.begin(115200);
    Serial.println("AHT20 DEMO");
    AHT.begin();
}

void loop()
{
    float humi, temp;

    int ret = AHT.getSensor(&humi, &temp);

    if(ret)     // GET DATA OK
    {
        Serial.print("humidity: ");
        Serial.print(humi*100);
        Serial.print("%\t temerature: ");
        Serial.println(temp);
    }
    else        // GET DATA FAIL
    {
        Serial.println("GET DATA FROM AHT20 FAIL");
    }

    delay(100);
}

// END FILE
```

Figure 8. Code sensor.

VIII. System Evaluation and Validation

During the initial three-month phase of the project, comprehensive testing was conducted on the prototype to ensure the accurate functionality of each component.

A. Sensors and components testing

1) *Temperature and Humidity sensor:* The sensor chosen was the GROVE AHT20 I2C Industrial Grade Temperature & Humidity Sensor as shown in **Error! Reference source not found.**. The device is capable of performing well in harsher environments according to its data sheets [7]. It has a temperature measurement range of -40 °C to 85 °C with an accuracy of ±0.3°C. In terms of relative humidity has a range of 0% to 100% with an accuracy of ±2% RH. This temperature range makes the sensor compatible with the temperature of the testing water conditions. It also has an operating voltage range of 2.0V to 5.5V which is similar to the microcontroller chosen. The sensor also has a Grove I2C interface which makes it compatible with the microcontroller and easier to work with.

Figure 9.Grove- AHT20 I2C Industrial Grade Temperature & Humidity Sensor.

2) *Microcontroller:* The power requirements of the microcontroller need to be met utilizing the ambient energy being collected. The ATMEGA328P Seeeduino board was a reasonable microcontroller to work with, the device used is shown in Figure 10. This microcontroller was chosen because proved that it was capable of being powered by ambient energy while also powering other sensors.

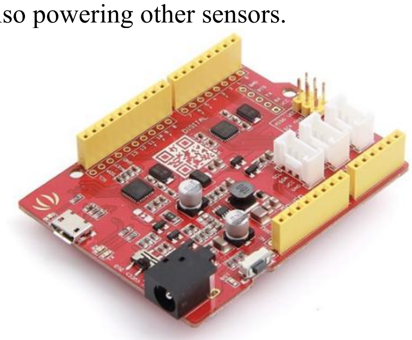

Figure 10.ATMEGA328P Seeeduino v4.2 board.

The microcontroller was connected to the Grove AHT20 sensor as shown in Figure 11 using I2C (Inter-Integrated Circuit), a synchronous serial communication bus. The sensor accuracy was validate as seen in Figure 12.

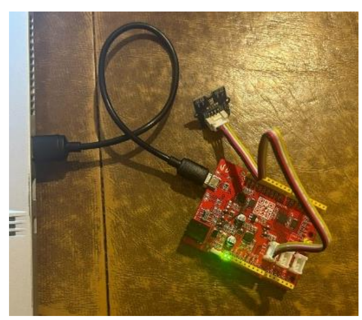

Figure 11. Testing the microcontroller and the sensor.

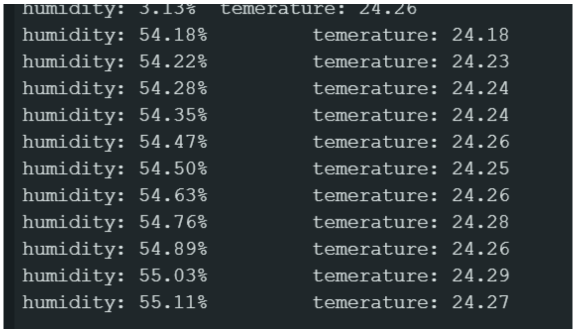

Figure 12. Temperature and humidity readings.

3) Mobile Application: The app created includes a Splash Page. The app requested Bluetooth permissions on this page and verification of the Bluetooth status before navigating to the Home Page. On the Home Page, the user has the availability to toggle Bluetooth on or off. In addition, this page scans for nearby devices and displays them. After connecting to the device, the user shall be directed to the Device Page. From the Device Page, users are allowed to input text and send it to the connected device. This page also displays the data received from the device. A disconnect button is also on this page. For a reference on all the screens created see Fig. 13.

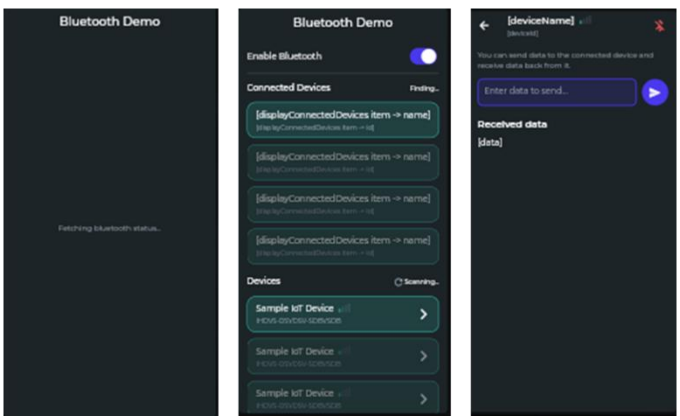

Fig. 13 Project Application interface.

4) Wave and Wind Energy Collection

1) Wave Collection: In the test that was completed wave energy was not sufficient to provide enough energy to power the microcontroller. This is likely to occur due several issues such as the testing environment being a pool where waves are very unlikely to reach any more than a few centimeters in height. Additionally, some friction between the tube and the buoy can be considered due to a lack of a linear guide system. The results of the first test between the buoy and the heave plate are shown in Table 2.

TABLE 2
WAVE ENERGY COLLECTED

Measurement	Current (mA)	Voltage (mV)	Power Generated (μW)
1st	0.659	12.10	7.97
2nd	1.121	20.60	23.10
3rd	1.225	22.50	27.60
4th	0.414	7.60	3.14
5th	1.165	21.40	24.90
6th	1.236	22.70	28.00
7th	0.729	13.40	9.77
8th	0.005	0.10	0.00
9th	0.376	6.90	2.59
10th	0.435	8.00	3.48
Average	0.737	13.53	13.06

2) Wind Collection: Since at higher wind speeds the turbines typically reach around 80% power production of the theoretical maximum over an open ocean. It can be expected to generate 1.314 W which should be sufficient in powering our microcontroller if given enough hibernation time. A sample is shown in Table 3.

TABLE 3
WIND ENERGY COLLECTED

	Energy (J)	
4-Bladed Turbine	4-Blade Turbine	3-Blade Turbine
Wind Speed = 4.2 m/s	0.142	0.111
Wind Speed = 4.6 m/s	0.169	0.257
Wind Speed = 4.8 m/s	0.330	0.277
Average	0.213	0.215

IX. CONCLUSION

Throughout the planet, there are many remote areas where electricity is difficult to reach. The urgency of providing solutions to underserved communities, exemplifies the value in powering devices with renewable energy in an efficient manner.

In terms of the project's design and results, the product showed better results for wind energy compared to the energy harnessed from wave energy. According to the data, the wind produced was about 80% of that produced in the Atlantic Ocean and is expected to generate about 1.314 W. If given more hibernation time, this would be sufficient to power the microcontroller. The designing and testing phases of a microcontroller powered by renewable energy allows future improvements including a calibrated thermometer, temperature and humidity measurements implementing a sensor as well as measuring the air quality and atmospheric pressure within the water. These ideas were contemplated and could be added to the project future work.

The development of a microcontroller powered by renewable energy sources, specifically ambient wind, and wave energy, is a smaller case sample that shows the enormous potential renewable energy has to offer and its influence in achieving environmental sustainability. The project's multifaceted goal of promoting renewable energy as reliable alternatives to fossil fuels inspires future generations to address climate change and remain environmentally involved.

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