# EcoCharge: Innovative Solar and Wind Charging Station Enabled by Solid Waste Contributions

**Jon Michael Magat, Jan Piolo Guiao, Noel Malana,**
**Mark Francis Pera, Reel Jerin Ignacio, Norman Bob Gomez**

*Electrical Engineering Program*
*School of Engineering, Architecture, and Information Technology Education, University of Saint Louis*
Tuguegarao City, Cagayan

***Abstract*— This study presents an innovative approach to waste disposal by leveraging microcontroller-controlled charging stations powered by solar and wind energy. Utilizing advanced sensors, the system detects incoming waste inputs, while intuitive indicators display the available charging time for each chamber. By utilizing designated buttons, users can allocate the available time from the minute counter to the charge timer, enabling charging in the corresponding relay slots 1 to 3. Extensive analysis revealed the charging percentages of batteries, identifying the peak performance occurring between 11 A.M. to 1 P.M., regardless of load presence. Additionally, the study investigated the hourly battery percentage discharged in the absence of any power source.**

***Keywords*— solar powered, wind powered, charging station, microcontroller***

## I. INTRODUCTION

Solid waste encompasses a wide range of discarded materials that are disposed of, burned, incinerated, recycled, or deemed waste-like. It includes various forms such as solids, liquids, semi-solids, or containers of gaseous substances [1]. In developing economies, the growing demand for production often leads to a significant volume of waste generation [2]. Unfortunately, inadequate waste management practices and improper waste disposal have become prevalent in many areas, especially in public spaces. This issue is particularly prominent in the Philippines, especially in urban regions, where solid waste management remains an ongoing challenge.

Data from the Philippine government reveals that the country produces approximately 43,684 tons of waste daily, with 4,609 tons consisting of plastic waste alone. Alarming statistics from a 2020 report by the World Wildlife Fund indicate that only 33 percent of the total plastic waste produced in the Philippines is properly collected and disposed of in sanitary landfills, while 35 percent is leaked into the environment. Moreover, a mere 9 percent undergoes recycling [3]. The Philippines has implemented the "Zero Waste Management" law, known as the Solid Waste Management Law, as a national program to address the issue of improper waste disposal [4]. However, its effectiveness has been limited. To mitigate the problem, some local government units have imposed penalties and initiated activities like clean-up drives and the placement of garbage bins in public areas.

In recent studies, technological advancements have been explored to incentivize proper waste disposal. One project, for instance, uses plastic bottles to provide free electrical charges for small-scale electronic devices, such as mobile phones, thus encouraging the public to dispose of plastic bottles properly for recycling purposes [5]. However, this system has limitations due to insufficient battery capacity and solar panel efficiency, preventing it from offering free charges for other types of solid waste materials.

This study aims to develop an enhanced project that offers free electrical charging for small electronic devices using solar and wind energy as more sustainable power sources. Unlike previous initiatives, this project aims to overcome the limitations by accepting non-biodegradable materials like plastic food wrappers. By creating this innovative solution, the project aims to raise awareness among the public about proper waste disposal practices while providing them with a valuable service of free electrical charging.

## II. RELATED WORKS

Various studies have explored the use of solar and wind energy in charging portable devices, each with its specific purpose and application. These works of literature and experiments have served as the foundation for developing the current project.

A study [6] designed a solar-powered charging station equipped with solar panels optimized for solar tracking. The station incorporates a microcontroller acting as a charge controller and an inverter to convert stored DC voltage in the batteries to AC voltage for output. This solution aims to harness renewable energy to address the emerging energy crisis. Solar canopy-style charging stations have been proposed for installation in sunny locations, bus stops, marketplaces, and even on windows of trains and buses, providing electric power to passengers during travel. Combining solar and wind hybrid systems in sunny and windy areas can ensure continuous power supply without extensive battery storage. Portable solar charging units can be deployed in office spaces as emergency response charging units during load shedding, reducing dependence on diesel generators and mitigating pollution [7].

Anothet proposed charging station architecture utilizes a small-scale wind turbine as the primary energy source [8]. A coordinated control strategy based on DC link voltage sensing is introduced to facilitate the operation of the charging facility in both standalone and grid-connected modes. The effectiveness of the proposed architecture and control algorithm is validated through simulations conducted using the MATLAB/SIMULINK toolbox. This research contributes to the development of sustainable and efficient charging infrastructure for PHEVs, ensuring seamless integration with microgrids while mitigating the risk of overloading distribution transformers.

A study [9] developed an alternative garbage disposal method using a microcontroller-operated charging station powered by solar energy. This system incentivizes users to dispose of plastic bottle scraps correctly by providing them with a power supply to charge electronic devices. The project aims to encourage proper waste management, inspire renewable energy usage, and create a pollution-free and healthy environment.

In summary, the existing literature and studies have contributed significantly to the design and development of the current project, shaping its overall system and approach.

## III. METHODS

Fig. 1 illustrates the block diagram of the system, highlighting its key components and their interactions. The charge controller plays a critical role in regulating the voltage and current generated by the solar panel and wind turbine to prevent battery overcharging. The 12-volt DC lithium battery serves as the energy storage unit within the system.

When solid waste is detected by the sensor, users can utilize a button interface to select the desired charging port for activation. The system incorporates LCDs that provide visual feedback by indicating the available charging time and the remaining battery capacity. This user-friendly interface enhances the overall usability and effectiveness of the system.

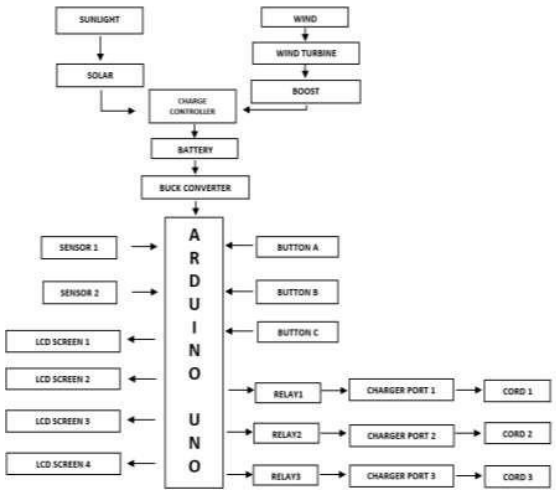


Fig. 1. Block Diagram of the System

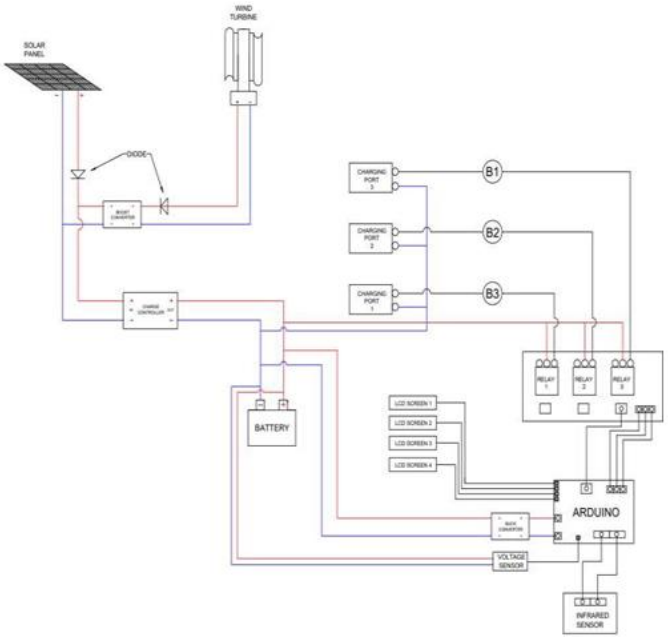


Fig. 2. Schematic Diagram of the System

Fig. 2 presents the schematic diagram of the system, showcasing the interconnections between the components. The solar panels and wind turbines are connected to diodes to enable unidirectional current flow. The boost converter is linked to the wind turbine, boosting the generated voltage to 12 volts. The charge controller ensures proper charging of the battery. The battery acts as a power source and storage for the system. The buck converter is connected in parallel to the battery, stepping down the voltage to supply the required voltage for the Arduino. The LCD screen displays the charging time and the number of detected wastes. Electronic relays, connected to the battery, control the charging process for the charging ports, which are responsible for charging mobile phones. Buttons assist the Arduino in activating the charge ports. The Arduino is connected to the electronic relays, issuing commands to control their operation. Infrared sensors, linked to the Arduino, detect objects, particularly solid waste.

## IV. RESULTS AND DISCUSSION

Figure 3 presents the actual image of the project, providing a visual representation of its physical setup. The solar panel is securely mounted using angle bars, ensuring its stability and optimal positioning for sunlight exposure. The wind propeller is ingeniously constructed using PVC pipe, harnessing the power of the wind to generate energy. To safeguard the project against corrosion, the circuit box is constructed using acrylic glass, offering durability and protection for the electrical connections. The device features four LCD screens, providing clear information and feedback to users. Additionally, three green lights indicate the charging time after pressing the buttons, while a blue light displays the number of detected wastes and the battery percentage of the system.

The sensor is strategically positioned within the upper part of the trash can, ensuring efficient detection of any waste that is deposited inside. This placement ensures that the system can accurately sense and respond to the presence of waste, enabling smooth operation and effective charging. The actual image depicted in Figure 3 showcases the tangible implementation of the project, highlighting its practicality and functional design.

Fig. 3. Working Prototype of the System

Table I displays the battery percentage readings obtained during the testing phase. At the start of the testing, the battery percentage was approximately 10%. The highest battery percentage was observed between 11 A.M. and 1 P.M., while the lowest battery percentage occurred from 7 A.M. to 9 A.M.

TABLE I. BATTERY PERCENTAGE WITHOUT LOAD

| Time | Initial battery percentage at 0 load | Final battery percentage at 0 load |
|---|---|---|
| 7am – 9am | 10% | 37.8% |
| 11am – 1pm | 10.3% | 45.5% |
| 3pm – 5pm | 10.7% | 39.6% |

TABLE II. BATTERY PERCENTAGE WITH LOAD

| Time | Initial battery percentage | | | Final battery percentage | | |
|---|---|---|---|---|---|---|
| | 1 load | 2 loads | 3 loads | 1 load | 2 loads | 3 loads |
| 7am – 9am | 30.2% | 30.1% | 30.2% | 43.8% | 32.9% | 13.4% |
| 11am – 1pm | 30.4% | 30.5% | 30.1% | 49.4% | 37.1% | 15.1% |
| 3pm – 5pm | 30.6% | 30.4% | 30.3% | 46.6% | 34.2% | 14.1% |

In Table II, the initial battery percentage with 1 to 3 loads was approximately 30% for each test. Throughout all three tests with varying loads, the highest battery percentage was consistently recorded during the 11 A.M. to 1 P.M. testing period. However, it is worth noting that the energy source was unable to sustain continuous operation with three loads. The battery percentage exhibited a decrease during these tests compared to the tests with only one or two loads, particularly during the 7 A.M. to 9 A.M. testing period.

TABLE III. DISCHARGING TIME OF THE SYSTEM OPERATED WITHOUT ANY POWER SOURCE

| Number of Loads Connected | Discharged Percent Per Hour |
|---|---|
| 0 | 3.1% |
| 1 | 11.2% |
| 2 | 18.4% |
| 3 | 28.3% |

Table III provides valuable insights into the discharged percentage per hour for different numbers of loads connected to the system. The discharged percentage refers to the rate at which the battery's charge decreases over time when various loads are actively consuming power. As the number of loads connected increases, the discharged percentage per hour also increases. When no load is connected (0 loads), the discharged percentage is recorded at 3.1% per hour. This indicates a relatively low discharge rate, implying that the battery's charge is being preserved efficiently when no loads are drawing power.

However, as the number of loads increases, the discharged percentage per hour rises significantly. With a single load connected, the discharged percentage increases to 11.2% per hour, indicating a higher rate of energy consumption. When two loads are connected, the discharged percentage per hour further increases to 18.4%. This suggests that the system experiences a greater power demand when multiple loads are active simultaneously, resulting in a faster depletion of the battery's charge. Notably, when three loads are connected, the discharged percentage per hour reaches its highest value at 28.3%. This indicates that the system's energy supply may struggle to meet the demands of three loads continuously, resulting in a more rapid discharge rate.

These findings highlight the importance of considering the number of loads connected to the system when assessing its overall performance and energy efficiency. It demonstrates that the system's capacity to sustain multiple loads simultaneously may be limited, potentially requiring optimizations such as energy management strategies or the addition of more robust power sources to meet higher power demands effectively.

Table IV presents the accuracy of the waste detection system in terms of its ability to correctly identify the size of the waste. Each trial indicates the expected size of the waste and the actual size detected by the system, along with remarks indicating whether the detection was correct or not.

TABLE IV. ACCURACY OF THE SYSTEM IN DETECTING WASTE

| Trial | Expected | Actual | Remarks |
|---|---|---|---|
| 1 | big | big | CORRECT |
| 2 | big | big | CORRECT |
| 3 | big | big | CORRECT |
| 4 | big | small | WRONG |
| 5 | big | big | CORRECT |
| 6 | big | big | CORRECT |
| 7 | big | big | CORRECT |
| 8 | big | small | WRONG |
| 9 | big | big | CORRECT |
| 10 | big | big | CORRECT |
| 11 | small | small | CORRECT |
| 12 | small | not detected | WRONG |
| 13 | small | not detected | WRONG |
| 14 | small | small | CORRECT |
| 15 | small | small | CORRECT |
| 16 | small | not detected | WRONG |
| 17 | small | big | WRONG |
| 18 | small | not detected | WRONG |
| 19 | small | not detected | WRONG |
| 20 | small | small | CORRECT |

The system demonstrates a commendable level of accuracy in detecting waste. In the majority of trials, denoted as "CORRECT" in the remarks column, the system successfully identifies the size of the waste as expected. This indicates that the waste detection mechanism is reliable and capable of distinguishing between different sizes of waste.

However, there are instances where the system encounters detection errors, labeled as "WRONG" in the remarks column. These errors occur when the system incorrectly identifies the size of the waste. For example, in trials 4, 8, 17, 18, and 19, the system mistakenly detects a different size than the expected size of the waste.

It is noteworthy that the system exhibits higher accuracy in detecting larger waste (designated as "big" in the expected and actual columns) compared to smaller waste (designated as "small"). The system achieves a higher correct detection rate for larger waste, while it struggles more with the accurate detection of smaller waste.

The table highlights the importance of further refining the waste detection algorithm, especially for smaller waste items, to improve the system's overall accuracy. Enhancements such as adjusting sensor sensitivity or incorporating advanced image recognition techniques could potentially address the errors observed in the detection of smaller waste.

## V. CONCLUSION

This study successfully developed and implemented a waste management system utilizing solar and wind energy for charging small electronic devices. The system effectively detects waste and provides free electrical charging based on the type of waste disposed of. The integration of solar panels, wind turbines, sensors, and a user-friendly interface demonstrates the feasibility and potential of renewable energy-powered waste management solutions. The system showed promising results in terms of accurate waste detection and reliable charging capabilities. However, further improvements are needed to enhance the accuracy of waste detection, particularly for smaller waste items. Overall, this study contributes to the advancement of sustainable waste management practices and highlights the potential of renewable energy sources in addressing waste disposal challenges.

Based on the findings and observations of this study, several recommendations can be made to further enhance the waste management system. Firstly, it is crucial to refine the waste detection algorithm, especially for smaller waste items, to improve accuracy and reduce detection errors. This can be achieved by exploring advanced image recognition techniques or fine-tuning sensor sensitivity. Additionally, the system's charging capacity should be optimized to ensure continuous and efficient charging of multiple devices. This can be accomplished by considering larger battery capacities or exploring energy storage solutions to sustain high-demand periods.

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