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An Innovative Concept for an Intelligent Organic Waste Collection Bin that Rewards Users in Oman

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***Abstract* - As urbanization accelerates in Oman, efficient organic waste management becomes a critical challenge. This paper presents the design and development of a novel Smart Organic Waste Collection bin (SOWCB) equipped with an innovative reward system to encourage and incentivize users for responsible waste disposal in Oman. The SOWCB integrates renewable energy and sensor technologies, including RFID, load sensors, and ultrasonic sensors connected to microcontrollers to monitor and optimize the waste collection process. The innovative reward system embedded in the design offers users tangible incentives for their environmentally responsible behaviour. Further, this incentive shall be claimed by the users from the sponsors in exchange for exposure to their business ads displayed through the bin. The development involves a multidisciplinary approach incorporating 2D and 3D design using Autodesk Inventor software, mechanical fabrication, and electronic and software engineering. The paper details the bin's novel technical aspects, scope for implementation and possible outcomes. The research evaluates the effectiveness of the proposed system through pilot studies conducted in selected areas of Oman, providing insights into user acceptance, system reliability and overall organic waste management improvements. This research aligns with Be'ah's vision "to conserve the environment of our beautiful Oman for our future generations".**

Keywords: Organic waste, SOWCB, Solar energy, sensors, reward.

I. INTRODUCTION

The tremendous increases in urbanization and economic growth have led to a significant rise in the amount of garbage that is being produced all over the globe. Oman has achieved the fastest progress in development within a short period among the countries that are members of the Gulf Cooperation Council (GCC) [1]. In 2012, the amount of municipal solid waste (MSW) generated in Oman was 1.5 metric tons, which is anticipated to increase to 1.89 metric tons by 2030 (Oman et al. Company, 2016). Because of the growing emissions of greenhouse gases (GHG), the Sultanate of Oman faces a complex problem due to the fast growth in the rates at which wastewater is produced. As seen in Table (1) below [2], the present trash production per year, consumption, moisture content, and average energy content of municipal solid waste in Oman demonstrate the potential for energy recovery. At the Point of generation (home), garbage in Oman is not divided into categories such as inorganic, organic, and recyclables. Instead, waste of all kinds is thrown carelessly into landfills. This is in contrast to the situation in industrialized nations. Regarding the use of organic wastes for energy recovery, the first step necessary in Oman is source separation [3].

Table 1: Waste composition of Oman and suitable Waste To Energy (WTE) options

Waste generation in 2016	Fraction	Composition (%)	Moisture content (%)	Average Energy Content(MJ kg-1	Suitable WTE technology
1.7 mt	Food waste	27	30	10	Biochemical and Thermal
	Plastic	21			Thermal
	Carbon	10			Thermal
	Glass	6			Not suitable for both
	Textile	6			Thermal
	Biowaste	5			Biochemical and thermal
	Paper	5			Thermal
	Wood	2			Thermal

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Solid waste in Oman is characterized by a very high percentage of recyclables, primarily paper and cardboard (15%), plastics (20.9%), metals (1.8%), and glass (4%) (Source: Waste Characterization and Quantification Survey; Be'ah, 2013). Before 2006, over 318 dumpsites, two sanitary landfills, and two transfer stations were available in the country, as shown in Figure 1 below. 2017, Be'ah was formed, and by 2018, all the dumpsites were closed. It has set a vision to achieve MSW per day per capita of less than 1 kg by 2040, as shown in Figure 2 below.

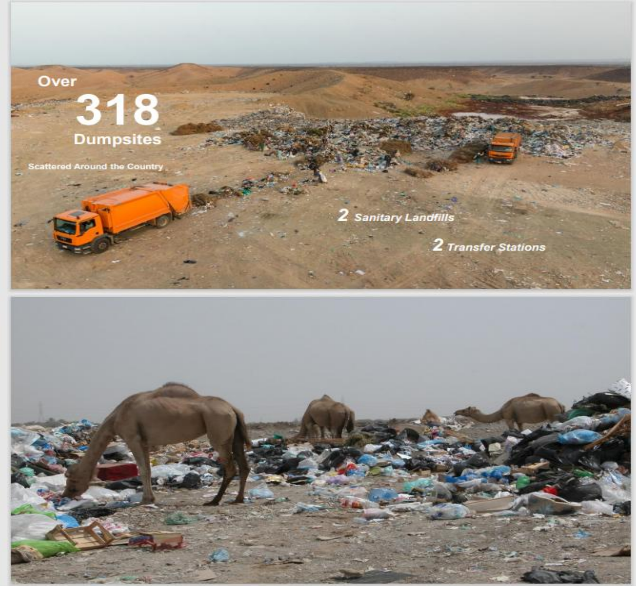

Figure 1: WMS before 2006 in Oman

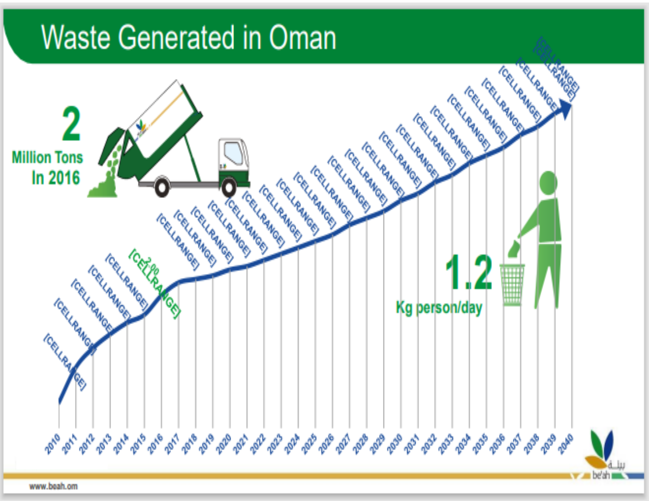

Figure 2: Waste generation in years in Oman

Waste contains different metals, recyclable materials, and energy-containing components—disposal of such waste materials results in the loss of natural resources. Studies conducted by experts show that the composition of non-organic municipal solid waste is such that it is endowed with a high-calorific value while incinerated and thus suitable for use as a fuel resource in waste-to-energy projects. Also, wet waste, which is organic waste, has a high potential of producing biogas from the digester or a good fertilizer from the composting unit, as shown in Figure 3 below.

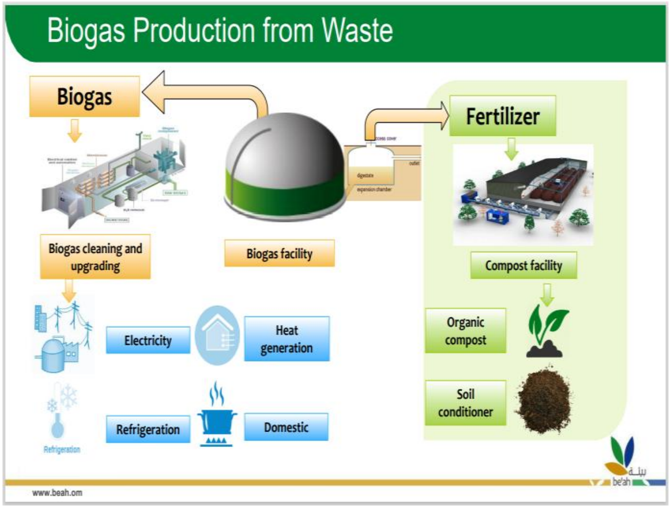

Figure 3: Biogas production from waste

II. LITERATURE REVIEW

Wastes in Oman are disposed of in landfills since there are no facilities for treating solid waste, except for a small amount of recycling. Based on the identified criteria, anaerobic digestion, followed by fermentation and incineration using the analytical hierarchy process, is the most suitable waste-to-energy technology for Oman, according to Wajeeha A. Qazi et al.'s study on Multi-criteria decision analysis of waste-to-energy technologies for municipal solid waste management in the Sultanate of Oman [4].

In order to provide baseline data for the development of a municipal solid waste management system, Thenmozhi Murugaian Palanivel et al. from Sultan Qaboos University conducted a study on the generation and composition of municipal solid waste in Muscat, Sultanate of Oman. They went to the summer and winter dumps to gather samples. The sample that was gathered was divided into several parts. Then, measurements and records were made for each component's weight and volume. With a density of 310 kg/m3, the daily production of MSW is 0.97 kg/day/person by weight and 3 x 10-3 m3/day/person by volume. According to the study, the MSW stream has the highest percentage of recyclable and biodegradable garbage. Composting, recycling, and energy recovery are examples of waste management strategies that could be used in the future to reduce the number of waste streams that are dumped in landfills [5].

In their paper Reward-based Intelligent Garbage Management System, Sandeep Bhatia and colleagues explored how wireless sensors, GSM, and wifi modules may be used to handle key garbage management issues intelligently. They

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concluded that the several obstacles to appropriate waste management might be effectively optimized within the scope of those sensors' and IoT's combined practical usage [6].

In their work on incentive systems for trash management, Ganesh Prasad Rao and colleagues tackled the issue of plastic waste management, suggesting an Internet of Things-based solution and introducing the notion of rewards to encourage the disposal of dry waste [7].

In their study on an IoT-based innovative garbage collection system alert system, Sadiq Mohamed Irfan and colleagues proposed an intelligent garbage truck collecting/tracking system that uses an ESP8266. Real-time truck data is sent to the government and can be accessed by an MIT app via the FIREBASE database system. Additionally, UBIDOTS uses an ultrasonic sensor to track the amount of rubbish in the vehicle [8].

S. Vinoth Kumar and T. Senthil Kumaran investigated Internet of Things-based intelligent waste monitoring and clearing systems. In their study, they presented an IOT-based innovative waste clean management system that uses sensor systems to detect the trash level above the dustbins. As soon as it was discovered, this system changed to address authorization via GSM/GPRS. A microcontroller served as the system's interface between the GSM/GPRS system and the sensor system. An Android application was created to monitor and combine the required data pertaining to the varying trash levels in various places. They made sure that India was clean and supported Swachh Bharat in maintaining a greener environment [9].

According to Mohammed F. M. et al.'s paper, "Effective Approach for Improving Municipal Solid Waste Management in Oman: Toward Sustainable Development," the most important factors to consider when choosing the optimal waste management strategy for Oman are those related to the economy and the environment. According to experts' preferences, the current landfilling practice is the best course of action for Oman. In their study, the Analytical Hierarchy Process (AHP) was employed to integrate the priorities of multiple criteria and four waste management scenarios into the hierarchy structure. While the status quo shown in scenario one did poorly, scenarios 2 and 3, which featured waste source separation combined with anaerobic digestion and recycling, respectively, ranked in the middle [10].

From the above survey, it is clear that more research is needed on smart organic waste collection bins suitable for the Oman waste collection management system. In this paper, we propose a novel design of bins with the concept of rewarding the users from the sponsors. The sponsors might be government organizations or private entities who can be profited by advertising their brand from the bin. Even though the different types of smart bins have been studied by many in our research, we have a novel design of smart bins harvesting solar energy for their operation and a unique method of rewarding the users.

2.1 Research Significance

The primary significance of this project is to develop a novel smart bin that gets its unique identity alongside municipal plastic bins across the Sultanate of Oman to collect organic waste. This collected waste is then transferred to waste to an energy conversion unit from where biogas and good compost can be generated and used for the betterment of the nation.

III. METHODOLOGY

3.1 Proposed System block diagram

Figure 4 shows the proposed block diagram of SOWCB, which includes the top box and bottom box mounted one over the other with a solar panel. The top box is an essential component comprising all electrical and sensor connections.

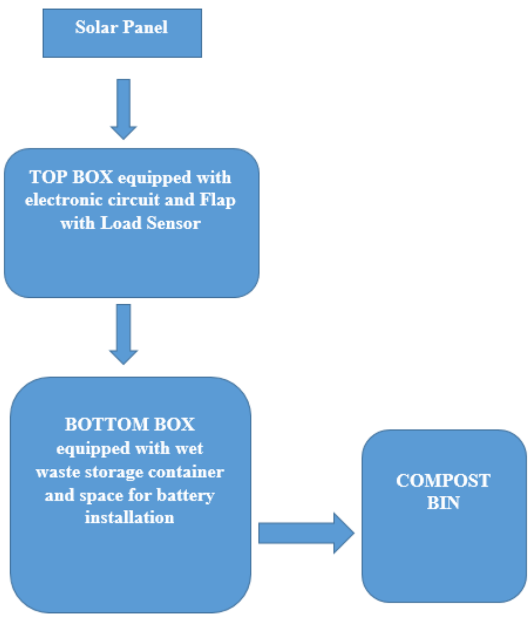

Figure 4: Block diagram of Proposed SOWCB

3.2 Proposed System Flow Chart

Figure 5 to 7 shows the flow chart for the proposed SOWCB. At stage I, the user responsibly separates the organic waste from the primary source of generation, and with the help of the assigned RFID tag, the user will proceed to stage II, where a user scans the RFID first, followed by an ultrasonic sensor displaying the message about the volume of bin available for dumping the waste. Based on the response, the

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door will open, and the user shall dump the waste in the Top box. The weight of the waste shall be measured by the calibrated load cell installed on the mechanical flap, which shall rotate around 450 to dump the waste into the secondary bin placed in the bottom box. The mechanical flap is connected with a stepper motor that controls the flap rotation.

Users get information like the weight of waste dumped and reward points earned on the display screen. Upon confirmation, the user shall close the top box lid and return. This cycle repeats for every user with valid RFID tags.

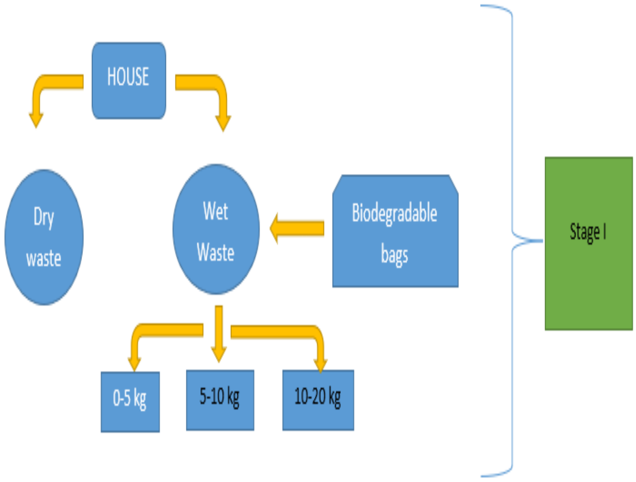

Figure 5: Flow chart stage I

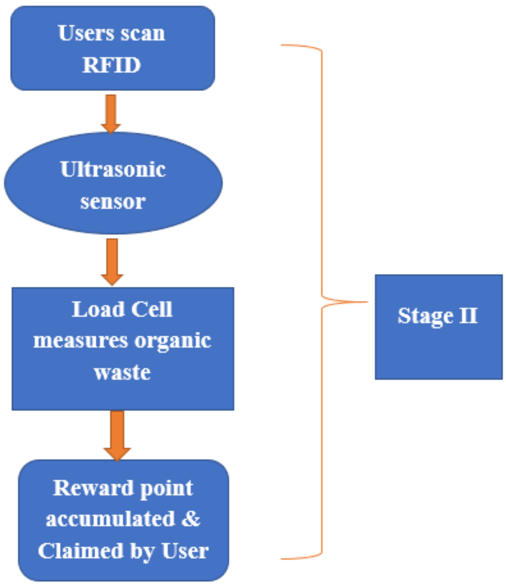

Figure 6: Flow chart stage II

The waste collected in the secondary bin is transferred to a composite bin or processing site on a regular basis for further actions, as shown in Figure 7 below. At the end of every month, the user reward points collected are calculated and converted into e-vouchers or coupons from the sponsorship firms and delivered to the users. The users can claim this at different outlets for discounts. The reward is computed as assuming 5 points for each 100 g of organic waste dumped: *Reward Point = (waste dumped/100) x 5……………… (1)*

For every 50 points, a gift voucher is awarded to the users during testing.

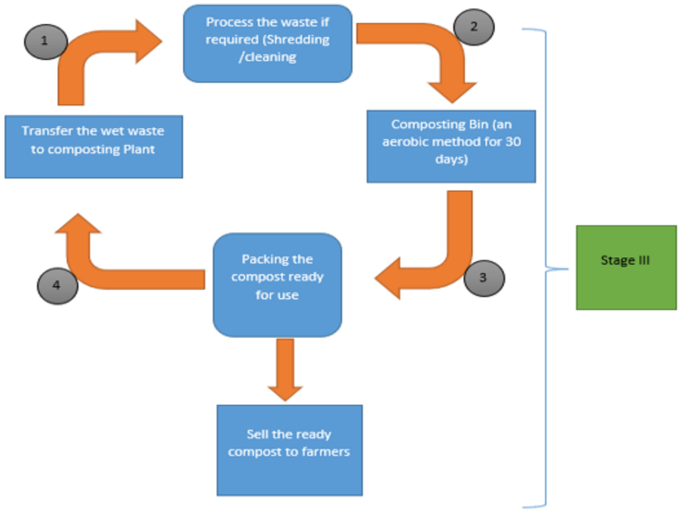

Figure 7: Flow chart stage III

3.3 Proposed System Hardware Block Diagram

Figure 8 below shows a system hardware block diagram consisting of a microcontroller, ultrasonic sensor, display unit, load cell, RFID reader, servo motor, electric lock mechanism with battery, solar module and panel.

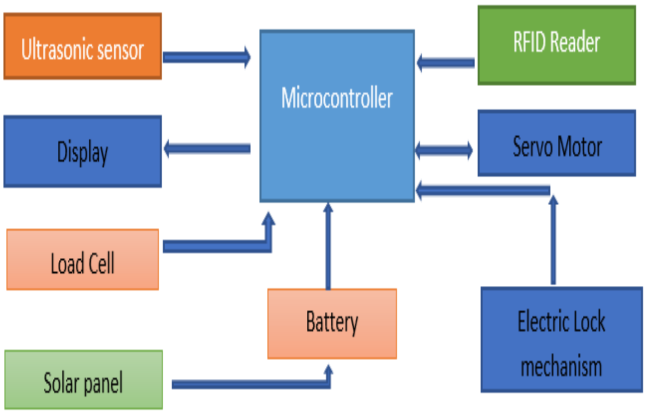

Figure 8: Block diagram for Hardware

3.4 Proposed System Circuit Diagram

Figure 9 below shows the circuit diagram with the ESP32 microcontroller. RFID RC522 is used with an HX711 load cell amplifier.

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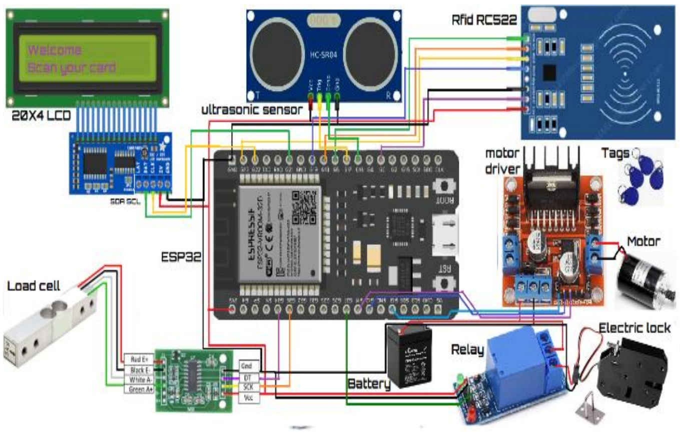

Figure 9: Circuit diagram

3.5 Proposed System 2D and 3D representation

Autodesk inventor is used to design the 3D Model of the conceptual SOWCB, as shown in Figs 10 and 11. The developed prototype is shown in Figure 12.

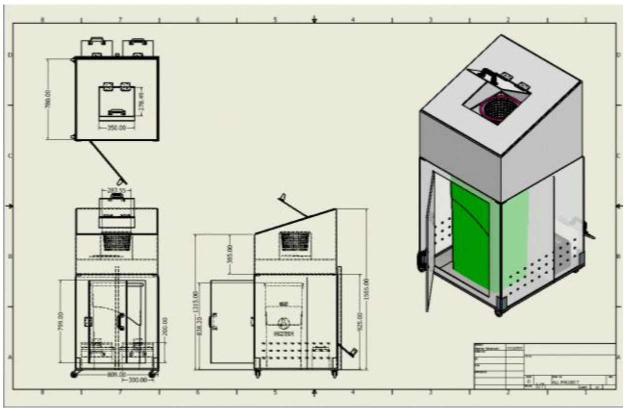

Figure 10: 2D and 2D drawing of proposed system

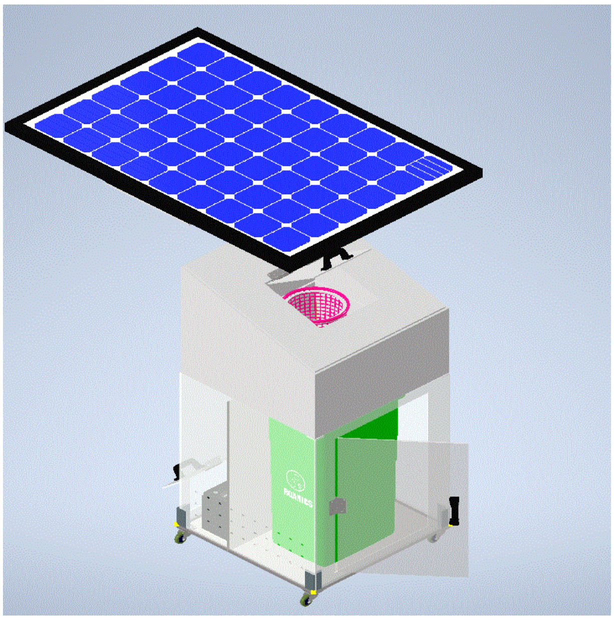

Figure 11: 3D model of conceptual SOWCB

Figure 12: Prototype of working model

IV. RESULTS AND DISCUSSIONS

The results demonstrate the successful implementation of innovative waste collection. The sensors effectively monitored the organic waste level and weight measurement, and the real-time data stored provided valuable insights into waste generation patterns and user rewards. The reward program showed promising results in increased user participation and improved waste disposal practices.

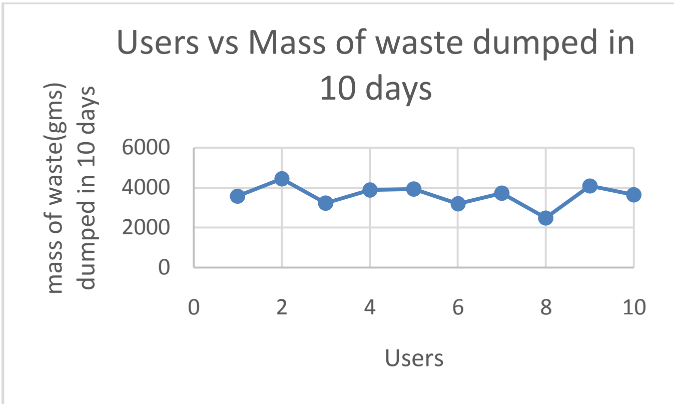

Figure 12: Users v/s mass of waste measured

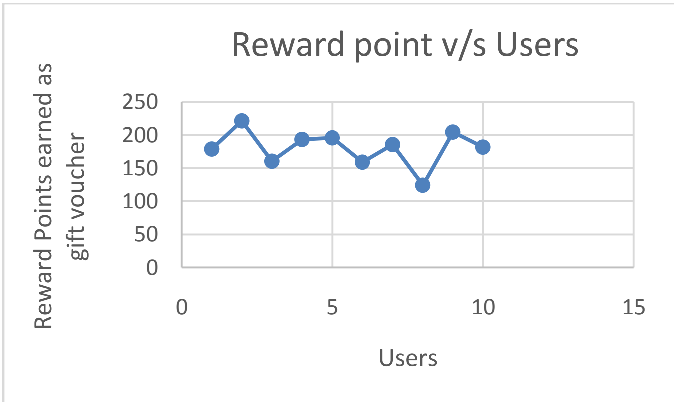

Figure 13: Reward points earned by users

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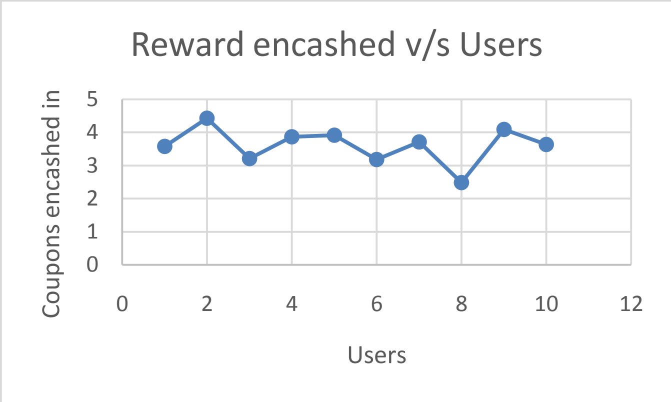

Figure 14: Reward enchased by users

In the present study, the research is limited to collecting organic waste and rewarding the user based on the computed reward system, as shown in (1). For a trial run, at the end of 10 days, the total waste dumped from individual users was measured, and the reward point was calculated. Users claimed further gift coupons and the same was used at sponsored outlets. The highest of 4 coupons and lowest of 2coupons were awarded to the identified ten users for ten days. The system demonstrated overall success; challenges such as technical glitches like sensor failure were noticed during the experiment and had to be fixed frequently. The system used a solar panel of 40 watts, successfully harvesting enough power to charge the 12 v 7Ah terminator TSLA7-12B Lead Acid Battery.

V. CONCLUSION

This research presents the design and execution of an intelligent organic waste-collecting container that has a particular rewarding function. The outcome showed increased efficiency in trash management and strong user engagement. The system offers an environmentally conscious way to improve organic waste disposal methods in a scalable and sustainable manner. Further research should focus on long-term monitoring and evaluation of the SOWCB, exploring opportunities for business expansion and addressing challenges identified in this study. Additionally, the scope for better advertising the sponsors' brand must be essential to meet the reward scheme effectively. Also, there is a need for a flat form to target awareness campaigns to reach maximum users and sponsors in the future.

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