
SenseBin: IoT-Based Solar Powered Smart Dustbin for Real-Time Waste Level, Gas Smell, and Lid Status Detection

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Abstract.

Rapid urbanization has increased solid waste, making timely collection difficult. This paper presents SenseBin, a solar-powered IoT smart bin with separate dry and wet waste compartments. Ultrasonic, MQ135, and lid sensors monitor fill level, gas conditions, and lid status. Data are sent to Firebase and displayed on a web dashboard. Testing showed effective real-time monitoring, making SenseBin suitable for smart-city waste management.

Keywords. IoT; smart waste-bin; waste management; gas sensing; solar system; real-time monitoring.

1. INTRODUCTION

Increasing urban waste creates collection and hygiene challenges [1]. Traditional bins lack real-time monitoring of fill level, gas, and lid status, causing delays [2,3]. SenseBin addresses these issues using ultrasonic, MQ135, and lid sensors with solar-battery power and cloud-based monitoring.

2. RELATED WORK

Zanella et al. [1] introduced IoT-based smart-city services, while Arebey et al. [2] used RFID, GPS, GPRS, and GIS for bin tracking. Navghane et al. [3] proposed ultrasonic-based smart bins. LoRaWAN and cloud-based systems were explored by Silva et al. [4] and Chen et al. [5]. Other studies [6–9] highlighted IoT, gas sensing, wireless networks, and energy-autonomous waste monitoring. Solar-powered and wireless IoT systems [10–12] further support the feasibility of outdoor smart-bin solutions. Table 1 compares these systems based on fill level, gas sensing, lid status, and solar power.

Table 1. Comparison of SenseBin with representative prior smart-bin systems.

Work	Fill-level sensing	Gas sensing	Lid status	Solar powered
[2]	Yes (RFID/GPS)	No	No	No
[3]	Yes	No	No	No
[4]	Yes (LoRa)	No	No	No
[5]	Yes	Limited	No	No
This work	Yes (Ultrasonic)	Yes (MQ135)	Yes	Yes

3. PROPOSED SOLUTION

System Overview

SenseBin is a dual smart-dustbin system for separately monitoring dry and wet waste. Each bin houses ultrasonic, gas and lid sensors connected to its own ESP controller. As shown in

Figure 1, the system has four parts: a power-supply unit (solar panel, charge controller, battery), the smart dustbin unit (sensors and controller), a cloud server, and a user interface comprising a web dashboard and mobile app for remote monitoring of fill level, gas condition, lid position and battery status.

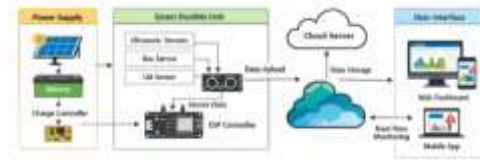


Figure 3.1. System architecture of the proposed SenseBin platform.

Working Principle

decomposition gases and the lid sensor monitors opening and closing. The ESP32 processes all readings and sends them to the cloud database for real-time dashboard monitoring.

4. HARDWARE ARCHITECTURE

Each bin uses an ESP32 [13] with ultrasonic, MQ135, lid, and battery sensors for real-time monitoring. Solar power provides energy, while battery voltage is monitored for power status [14].

5. SOFTWARE ARCHITECTURE

The firmware collects and transmits sensor data to Firebase [15]. The web dashboard displays fill level, gas, lid, and battery status in real time.



Figure 5.1. Data and control flow of the SenseBin smart waste-management system.

6. MATHEMATICAL MODELING AND CALCULATIONS

Fill Level Calculation

With H being the height of the internal bin (cm) and d, the distance measured by the ultrasonic sensor (cm), the is given by (1):

$$Fill\ Level\ (\%) = \frac{H-d}{H} \times 100 \dots (1)$$

Once a threshold has been met (e.g. bin is 80% full), it can be collected.

Battery Percentage Calculation

Let V_m be the battery voltage at a current time and V_{min} / V_{max} , the safe minimum / maximum battery voltages. The battery capacity is calculated from (2):

$$\text{Battery Percentage (\%)} = \frac{V_m - V_{min}}{V_{max} - V_{min}} \times 100 \dots (2)$$

Gas Level Threshold Logic

If the measurements of the MQ135 sensor G are higher than a certain threshold $G_{threshold}$, the air is considered unsafe, as expressed in (3):

$$\text{If } G > G_{threshold}, \text{ Gas Condition} = \text{Unsafe} \dots (3)$$

The full classification used by SenseBin is summarized in Table 2.

Table 2. Gas-level threshold classification using the MQ135 sensor.

Sensor Value Range	Gas Level Classification	System Status
0 – 150	Safe	Normal
151 – 300	Moderate	Warning
Above 300	Toxic	Unsafe

7. RESULTS

The performance of SenseBin was tested under real-life conditions. The unit continuously logged the fill level, gas quality, lid status and battery charge and fed data to the dashboard in real time with no appreciable latency. Sensor readings were consistent for different fill levels and conditions. Observations on sensing unit are summarised in Table 3.

Table 3. Observations from SenseBin sensing units.

Parameter	Sensor Used	Observation
Waste fill level	Ultrasonic sensor	Accurate, consistent distance measurement
Lid status	Push button	Pressed = closed; not pressed = open
Gas presence	MQ135 gas sensor	Clear response to decomposition gases
Gas classification	MQ135 gas sensor	Reliable safe / unsafe identification
Dashboard update	ESP + cloud	Real-time updates without delay

Figure 7.1 shows the hardware implementation of SenseBin, including the ESP32, connected sensors, power-management circuitry, and the assembled dual dry/wet waste-bin prototype.



Figure 7.1 SenseBin Circuit, Physical Prototype, and Web Dashboard.

8. DISCUSSIONS

Low-cost sensors, ESP32, and Firebase enabled effective real-time monitoring of fill level, gas, and lid status, improving on conventional systems [2–5]. Solar-battery power supports energy-independent operation [10–12]. Limitations include the MQ135’s non-specific gas detection and the prototype’s small capacity.

9. CONCLUSIONS

SenseBin provides solar-powered, real-time monitoring of waste level, gas, and lid status using ultrasonic, MQ135, and lid sensors with ESP32 and Firebase. Future work includes selective gas detection, large-scale deployment, and route optimization.

10. REFERENCES

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