Smart Gas Guardian: Gas Monitoring and Alert System

Anand Kumar B[1] Sukruth S[2] Kavya B R[3]

Dept. of CS&E
AMC Engineering College
Bangalore, India
anandkumar.mb@gmail.com

Dept. of CS&E
AMC Engineering College
Bangalore, India
sukruths18@gmail.com

Dept. of CS&E
AMC Engineering College
Bangalore, India
kavyabhat0503@gmail.com

***Abstract*— Designed to improve safety and gas usage in homes powered by liquefied petroleum gas (LPG) cylinders, the Smart Gas Guardian is a safe and intelligent system with a friendly interface. The system utilizes an MQ6 sensor to detect gas remaining in the tank which is tracked via a weight sensor (load cell) connected through an HX711 amplifier. An ESP32 microcontroller collects this data in real-time and sends it to a Flask-based backend server. This data is first stored in a MongoDB database and in it, the data is analyzed with a machine learning model that predicts the remaining gas utilities for given days. Using the model, machine learning analyzes the household's past usage patterns. In turn, this data can be retrieved seamlessly using a mobile application developed with Flutter which provides live updates on gas levels, low gas alerts, and predictive data that serves gas utilitarian planning. Combining machine learning technology with the Internet of Things serves as a practical and widespread responsive solution towards safety and smarter gas management in households with the Smart Gas Guardian.**

1. INTRODUCTION

Liquefied Petroleum Gas, commonly known as LPG, is a vital energy source that powers cooking and heating in many homes, hostels, and small eateries. It's popular because it's affordable, efficient, and burns cleanly, making it a trusted fuel for daily life. However, despite these benefits, LPG carries some hidden dangers if it's not carefully monitored. Many people still estimate how much gas is left by simply lifting the cylinder or only realize there's a leak when they smell gas in the air. These old-school methods aren't just unreliable; they can actually put people in harm's way. Running out of gas in the middle of cooking or, worse, an undetected gas leak can lead to accidents, fires, or health problems.

This risky situation is mainly due to the lack of smart, real time monitoring tools that can give early warnings. Most households don't have access to systems that track gas usage continuously or alert them to leaks before things get dangerous. That's why there's a growing need for a practical solution that combines technology with everyday usability — something that helps families stay safe and manage their gas levels smarter.

Our project, , responds to this need

Smart Gas Guardian

by offering an intelligent IoT-based system that continuously monitors LPG cylinders. It measures the gas amount using a sensitive load cell and detects leaks with a gas sensor, all controlled by a compact and powerful microcontroller. The data is sent wirelessly to a user-friendly mobile app, giving people clear, real-time updates and alerts. Beyond just tracking gas, the system also learns from past consumption to predict when the gas will run low, helping users avoid unexpected shortages.

In short, the Smart Gas Guardian isn't just about technology, it's designed with people in mind, making LPG usage safer, more reliable, and easier to manage.

2. RELATED WORK

Over the past few years, keeping homes safe with smart technology has become much more than a luxury—it's quickly turning into a necessity, especially when it comes to something as crucial as LPG gas. Researchers and engineers around the world have taken notice and stepped up by designing a variety of intelligent LPG monitoring systems, each introducing fresh ideas and clever solutions to age-old household safety worries.

Take, for example, some of the earlier systems that set the stage for today's advancements. Many of these used the classic combination of a gas sensor, like the MQ-6, and a load cell to keep track of the cylinder's remaining gas. These setups often connected to microcontrollers such as Arduino or ESP32 and sent data straight to the cloud, allowing families to monitor their gas supplies from an app or website. Whenever something went wrong—maybe the gas level dropped too low or a leak was detected—these systems would spring into action, sounding buzzers, sending notifications, and sometimes even shutting off the regulator automatically to keep everyone safe.

Despite these impressive steps forward, most early solutions weren't perfect. A recurring gap was the lack of "smarts" that could go beyond just monitoring; they often didn't look ahead to predict when the gas might actually run out based on each family's unique routine. Manual calibration was pretty common and the sensors, especially the load cells, could be thrown off by things as simple as a hot day or a power cut. Plus, the interfaces were usually just basic displays or simple phone notifications, making them less appealing and sometimes confusing for everyday users, especially those not so comfortable with tech.

Other projects tried to address user-friendliness by showing live updates via popular apps like Blynk or adding local LCD displays for instant feedback. However, these too were often limited to the basics: "Is there enough gas? Is there a leak?" Very few ventured into areas like predicting future needs, helping users plan cylinder refills in advance, or integrating with external services, such as gas supply companies for automatic top-ups.

All these creative attempts share one clear goal: to make LPG use less risky and life a little easier. Yet, in talking to users and reviewing the latest research, it's apparent there's still room for improvement, especially by adding predictive analytics, ensuring systems work during internet or power outages, and building even friendlier, more intuitive interfaces that anyone can use with confidence.

Our work with Smart Gas Guardian aims to fill these gaps. By blending predictive power with reliable, real-time monitoring, and wrapping it all in an easy-to-use mobile app, we hope to bring both peace of mind and genuine convenience to every LPG user—no matter where they live or how tech savvy they are.

3. PROPOSED WORK

Managing LPG cylinders safely and efficiently in everyday settings can be challenging, especially when current methods often rely on guesswork or outdated techniques. To address this, we have developed , an

Smart Gas Guardian

IoT-based system that continuously monitors gas levels and detects leaks to provide timely alerts and predictive insights, all designed with user convenience and safety in mind.

At its core, the system uses a 20-kilogram capacity load cell paired with an HX711 amplifier module to accurately measure the weight of an LPG cylinder. This setup allows us to determine the remaining gas by tracking subtle changes in the cylinder's load. In parallel, an MQ-6 gas sensor acts like a sensitive sentinel, detecting even tiny amounts of LPG in the surrounding environment that could indicate leaks.

Both sensors are interfaced with a compact yet powerful ESP32 NodeMCU microcontroller, which serves as the system's brain. This device continuously collects sensor readings, processes them locally, and transmits the data over Wi-Fi to a backend server built with Flask — a lightweight Python web framework chosen for its simplicity and scalability.

On the server side, incoming data undergoes validation and organization before being stored in a MongoDB database, optimized for handling frequent, time-stamped sensor updates. What truly sets this system apart is an integrated machine learning model embedded within the backend. By analyzing historical consumption patterns specific to each household, the model can forecast approximately when the LPG supply is likely to run low, enabling users to plan refills proactively rather than reactively facing sudden shortages.

User interaction is streamlined through a cross-platform mobile application developed using Flutter. The app displays real-time gas levels, issues immediate alerts for any detected leaks, and features predictive notifications to remind users ahead of time when their gas is nearing depletion. The interface is designed for simplicity and accessibility, ensuring that even individuals with minimal technical experience can confidently use the system.

Importantly, all hardware components — the ESP32, load cell, HX711 amplifier, and MQ-6 sensor — are chosen for their affordability and availability, making the Smart Gas Guardian an economically viable solution for a wide range of households, including those in rural or resource-constrained environments. The device requires no specialized infrastructure beyond a stable power supply and Wi-Fi connectivity, and its modular design allows for easy installation and future scalability.

The proposed solution integrates precise sensing, intelligent data processing, and user-centric design to create a reliable, cost-effective LPG monitoring system. It not only enhances safety by providing early leak detection but also improves user convenience through predictive analytics, helping households manage their LPG use more thoughtfully and securely.

4. ARCHITECTURE

4.1 System Architecture

The proposed Smart Gas Monitoring System follows a modular architecture that integrates sensing hardware, a backend server, a machine learning prediction model, a MongoDB database, and a Flutter-based mobile application. This setup allows seamless real-time monitoring of gas leakage and LPG cylinder usage. The entire flow and component interaction are illustrated in Figure 1. The sensing module collects weight and gas concentration data, which is transmitted to the backend for processing and storage. The mobile application fetches this data to provide users with real time alerts and insights on gas sufficiency and safety.

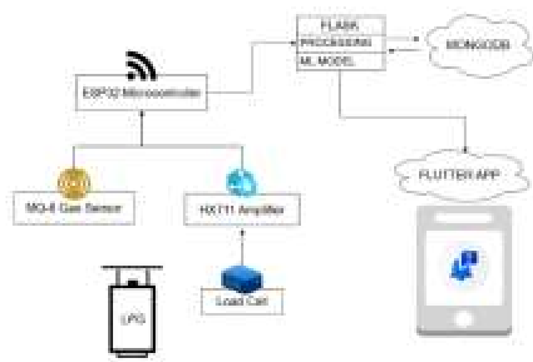

Figure 1. System Architecture

4.1.1 Sensor Unit (ESP32 + Sensors):

At the forefront of the system is the Sensor Unit, which consists of an ESP32 NodeMCU microcontroller connected to two primary sensors. The load cell, paired with an HX711 amplifier, continuously measures the weight of the LPG cylinder, offering precise and real-time tracking of gas consumption by detecting subtle weight changes. Alongside this, the MQ-6 gas sensor constantly monitors the surrounding air for any traces of LPG, acting as an early warning detector for leaks. Together, these sensors provide a comprehensive snapshot of both gas quantity and safety status, while the ESP32 manages data acquisition and pre-processing before transmitting the information wirelessly.

4.1.2 Backend Server (Flask):

Data collected by the sensors is sent via Wi-Fi to the Backend Server, which is developed using Flask, a lightweight and flexible Python web framework. The server serves as the central hub for receiving, validating, and organizing sensor inputs. Incoming data undergoes rigorous parsing and consistency checks to ensure reliability before it is made available for further analysis. Additionally, the Flask server exposes RESTful APIs that allow seamless communication with client applications, supporting requests for real-time status updates and historical data retrieval. This server-side layer underpins the system's responsiveness and scalability.

4.1.3 Prediction Engine (Machine Learning):

A distinctive feature of the system is the inclusion of a Prediction Engine embedded within the backend environment. This engine employs a machine learning model trained on historical gas consumption data to intelligently forecast the remaining usability of the LPG cylinder. By analysing usage trends unique to each household, the model classifies gas availability into categories such as sufficient, low, or critical. This forward-looking capability empowers users with actionable insights, enabling them to anticipate refills and avoid unexpected shortages, thereby improving convenience and safety.

4.1.4 Database (MongoDB):

All sensor data and prediction results are stored in a MongoDB NoSQL database, chosen for its strength in handling time-series data with frequent writes and reads. MongoDB's flexible schema design and robust indexing allow efficient storage of continuous streaming data, accommodating dynamic updates while providing quick access for analytics and user queries. This centralized data repository supports both real-time monitoring and retrospective analysis, making it an essential pillar of the Smart Gas Guardian's data infrastructure.

4.1.5 Mobile Application (Flutter):

User interaction is facilitated through an intuitive mobile application developed with Flutter, a modern cross-platform framework. The app provides a clean, easily navigable dashboard presenting current gas levels, leak alerts, and predictive notifications. Its design prioritizes accessibility, ensuring that users of varied technical backgrounds can effortlessly monitor their LPG cylinder status and receive timely warnings directly on their smartphones. By connecting to the backend via secure API calls, the app delivers continuous, real-time feedback and fosters proactive gas management, enhancing overall user safety and convenience.

4.1.6 Communication Network:

The ESP32 communicates with the Flask server over a Wi Fi network, enabling remote data transmission. The mobile application either connects through the same local network or via the internet, depending on the deployment scenario. This communication infrastructure ensures that data flows smoothly between the sensing layer, processing backend, and user interface, making the system robust and scalable.

The Smart Gas Monitoring System architecture as illustrated in Figure 1 effectively combines sensing, processing, prediction, and user interaction for real-time LPG monitoring. The ESP32 collects data from gas and weight sensors, which is processed by a Flask backend and analyzed by a machine learning model. Data is stored in MongoDB and accessed via a Flutter-based mobile app, ensuring timely alerts and remote access. This modular, scalable design enhances household safety and enables future upgrades.

4.2 Sequence Activity

The interaction between the key components of the Smart Gas Guardian system follows a smooth and intelligent process designed to keep users informed and safe at all times. It all starts when the ESP32 microcontroller powers on and begins initializing the system. The first task is to keep track of how much gas is left in the cylinder. To do this, the load cell reads the cylinder's weight and sends this analog signal to the HX711 amplifier, which converts it into a digital format that the ESP32 can understand.

Once the ESP32 receives this digital weight data, it processes the information to estimate how much LPG is left. But the smart part doesn't stop there—this data is also passed through a machine learning prediction model. The model analyzes both the current weight and historical usage patterns to determine if the gas supply is sufficient, low, or in danger of running out soon. This way, users can plan ahead rather than face unexpected gas outages.

Figure 2. Sequence Activity Diagram

At the same time, the MQ-6 gas sensor is on alert, continuously sniffing the air for any traces of leaking gas. If it detects even a small amount, it immediately signals the ESP32. The complete flow is illustrated in Figure 2.

Whether it's a drop in gas levels or a potential leak, the ESP32 responds right away. It sends real-time alerts and updated gas status directly to the mobile application, where users can view everything through a clean, easy-to-understand dashboard. The app also provides notifications to warn users of critical situations—like dangerously low gas levels or a detected leak—so they can take action quickly.

This entire flow happens seamlessly in the background, offering a reliable, intelligent, and user-friendly experience that helps households stay safe and manage their LPG usage more efficiently.

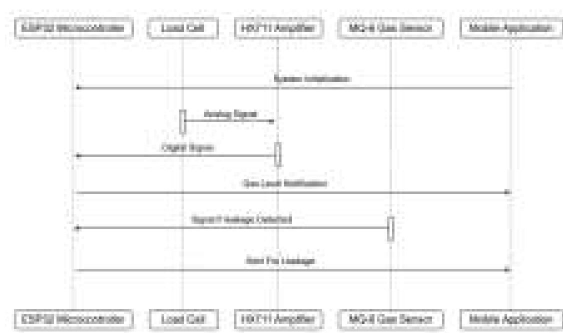

Figure 3. Flutter Mobile Application

Figure 3 represents the appearance of Mobile application developed for Smart Gas Guardian. This mobile UI shows real-time gas data with a 43.50% gas level. It indicates a "Medium – Monitor Level" status, suggesting caution. The "Refresh Data" button updates the reading.

4.3 Equations

The load cell weight measurement formula using an HX711 amplifier is:

the project proves that affordable, widely available components can be assembled into a powerful, real-world solution. The Smart Gas Guardian successfully meets its technical objectives and shows promise for real-life deployment. Future enhancements such as voice alerts, SMS backups, and AI-powered predictions could further boost its usefulness, making it a reliable addition to modern smart homes.

Weight (kg) = (V_{out} – Offset) Scale
(1) where: V_{out}: Raw output from HX71

Offset: Calibration zero point (when no load)
Scale: Calibration factor (determined during calibration using known weights).

Equation (1) represents the weight measurement using an HX711 amplifier, where the raw output is adjusted by subtracting the offset and dividing by a calibration factor to obtain the actual weight. This ensures accurate load cell readings after calibration with known weights.

The formula for calculating the percentage of gas remaining:

$$W_{current} – W_{empty}$$

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$$\text{Gas \% Remaining} = 100W_{full} - W_{empty} \quad (2)$$

where:
$W_{current}$: the current measured weight
W_{empty} : the tare weight (empty cylinder weight)
W_{full} : the full cylinder weight.
and documentation greatly contributed to the successful completion of this research. The availability of technical references related to IoT, ESP32 microcontrollers, MQ-6 sensors, and load cell integration played a key role in the development of the Smart Gas Guardian system.

Equation (2) calculates the percentage of gas remaining in the cylinder by comparing the current measured weight with the empty and full cylinder weights. This helps estimate the usable gas left for monitoring and predictive analysis.

While not a formula, gas leakage detection using the MQ-6 sensor works on threshold comparison:

If PPM(MQ6) > Safe Threshold, then ALERT

The sensor outputs analog values that are mapped to gas concentration (in PPM - parts per million). The threshold (e.g., 200 PPM for LPG) is experimentally defined based on safety limits.

5. CONCLUSION

The Smart Gas Guardian project showcases an effective use of IoT Technologies and Optimization (Trends and Future Directions) (ICRITO).

technology to enhance home safety and convenience by addressing two major concerns—unexpected LPG exhaustion and gas leaks. It utilizes an ESP32 NodeMCU microcontroller, MQ-6 gas sensor, and a load cell to monitor gas levels and detect leaks in real time, ensuring users are im-mediately alerted to potential hazards. A key feature of this system is its mobile application, which enables users to remotely track gas status and receive instant notifications, al-lowing for timely preventive actions. This user-centric approach not only improves safety but also adds everyday convenience. The system further supports efficient gas usage by analyzing historical consumption data, helping users predict refills and better manage re-sources. With cloud storage and wireless connectivity, real-time data access and scalability are ensured, allowing for future upgrades. Developed with a focus on cost-effectiveness and practicality,

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