Comparative Performance Analysis of Gas and Smoke Sensors for Enhanced Safety in Student Accommodations

Donald Ntombela,
Electrical & Electronic Engineering Technology
Eng. Faculty, University of Johannesburg
Johannesburg, South Africa
222080052@student.uj.ac.za

Ahmed Ali
Electrical & Electronic Engineering Technology
University of Johannesburg
Johannesburg, South Africa
aali@uj.ac.za

***Abstract*— Student accommodation environments present recurring fire and gas hazards due to the extensive use of LPG stoves and electrical heating appliances. This paper conducts a comparative performance analysis of low-cost semiconductor sensors—MQ-2, MQ-5, and MQ-6 for LPG/butane detection, MQ-9 and MQ-135 for smoke and CO detection, and the MLX90614 infrared sensor for temperature monitoring. Controlled experiments were performed to determine each sensor's sensitivity (RS/R_0 vs concentration), thermal stability (RS/R_0 vs temperature), and cross-sensitivity. Results show that MQ-2 delivers the steepest RS/R_0 drop with increasing gas concentration, confirming its high sensitivity to LPG, while MQ-6 offers moderate but consistent response with excellent temperature stability. MQ-5 maintained near-flat output across conditions, suggesting strong baseline reliability. Under smoke conditions, MQ-9 exhibited high responsiveness to combustion gases whereas MQ-135 provided steady readings suitable for smoke density tracking. MLX90614 recorded rapid temperature rises consistent with smoke events, reinforcing its usefulness for confirming flames or overheating. These findings demonstrate that a hybrid multi-sensor configuration can achieve early hazard detection and reduce false alarms in student residences using inexpensive and accessible hardware.**

Keywords—Gas sensors, Smoke detectors, MQ-2, MQ-5, MQ-6, MQ-9, MQ-135, Sensor performance, LPG leak detection, Fire detection, multi-sensor system, Student accommodation safety.

I. INTRODUCTION

Fire outbreaks and gas leaks are significant safety threats in residential settings, especially student accommodations where cooking and heating appliances are common. In particular, leakage of Liquefied Petroleum Gas (LPG) can lead to fires or explosions if not detected early [1]. Similarly, smoldering fires produce smoke and toxic gases (like carbon monoxide) before escalating. Traditional safety devices (such as standalone smoke alarms or carbon monoxide detectors) address some of these hazards, but an optimal safety system would detect a broader range of warning signs including flammable gas buildup, smoke, and abnormal heat to provide early and reliable alerts. Multi-sensor fire detectors that combine smoke and heat or gas sensors have been shown to reduce false alarms and improve response times compared to single-sensor detectors [2].

Low-cost semiconductor gas sensors of the MQ series have become popular for such applications due to their affordability and sensitivity [1]. These metal-oxide (SnO_2) sensors can detect combustible gases and air contaminants by a change in resistance when target gases are present [2]. A variety of MQ sensors exist, each tuned to different gases (or groups of gases). For example, the MQ-2 sensor detects methane, butane, LPG, hydrogen and even smoke, the MQ-5 targets natural gas (methane) and LPG, the MQ-6 is sensitive primarily to LPG (isobutane/propane), the MQ-7 and MQ-9 target carbon monoxide (with MQ-9 also responding to other flammable gases), and the MQ-135 monitors air quality, being sensitive to various pollutants including ammonia, benzene, and smoke [3]. By selecting an appropriate combination of these sensors, one can cover the most likely hazards in a student residence LPG or gas leaks (from stoves or heaters), and smoke/CO from fires.

This research focuses on the performance of three gas sensors (MQ-2, MQ-5, MQ-6) for LPG/butane detection, two sensors for smoke and combustion gases (MQ-9 for CO/flammable gas, and MQ-135 for smoke/toxic gases), and an infrared thermometer (Melexis MLX90614) for contactless temperature monitoring. The goal is to evaluate and compare their sensitivities, response times, and cross-sensitivities in detecting simulated hazardous conditions, and to assess how combining their outputs can enhance overall safety. Prior studies have investigated individual or paired sensor performance for instance, Galceran *et al.* compared MQ-2 vs MQ-6 for LPG leak detection and found both effective with MQ-6 being more sensitive in terms of gas concentration readings [1]. Other works have demonstrated that combining CO sensors with smoke detectors can significantly improve fire detection while reducing false alarms [2]. Building on these insights, our work provides a comprehensive analysis of multiple MQ sensors in a unified experiment and explores an integrated multi-sensor approach tailored for student accommodations.

The rest of this paper is organized as follows: Section II provides background on the sensors' working principles and related literature. Section III describes the experimental setup and methodology for testing sensor response to gas, smoke, and heat. Section IV presents the results, including response time graphs, sensitivity curves, and correlation between temperature and smoke readings. Section V discusses the implications of these results, such as sensor selection, placement, and multi-sensor data fusion for false alarm reduction. Section VI concludes the findings and suggests improvements for practical implementation. Finally, Section VII provides a brief author biography.

II. Background and Literature review

Traditional smoke alarms (photoelectric or ionization types) are standard in campus housing for detecting fires, but they respond primarily to particulate smoke and may not detect invisible combustible gases or heat until a fire is well underway. Dedicated **gas leak detectors** (for LPG, natural gas, or CO) are less common in dorms due to cost or retrofitting issues [1]. The MQ series of gas sensors offers a low-cost alternative and these are tin dioxide (SnO_2) semiconductor sensors on a small alumina ceramic tube with an internal heating element [4][5]. In clean air, the SnO_2 surface has low conductivity; when exposed to certain gases, the gas molecules undergo surface reactions that reduce the sensor's resistance (increasing conductivity) in proportion to gas concentration [2][5]. The change in resistance is measured via a simple voltage divider circuit, yielding an analog voltage signal that can be correlated to gas ppm (parts per million). Each MQ sensor type is formulated or doped to target specific gases, though cross-sensitivity is common [4][6].

MQ-2 is an archetypal **flammable gas and smoke sensor**. It has a broad detection range (approx. 200–10000 ppm) for gases including LPG (propane/butane), methane, hydrogen, carbon monoxide, alcohol vapor, and also is sensitive to smoke particles [5]. This versatility makes MQ-2 popular for general-purpose safety alarms, capable of detecting both gas leaks and the presence of smoke from a fire. However, its wide sensitivity means it may trigger on benign sources (e.g. alcohol fumes or cooking smoke) if not calibrated properly.

MQ-5 is targeted for **natural gas (methane) and LPG** detection [3]. It has high sensitivity and quick reaction to combustible gas, and its module often includes a built-in potentiometer and signal conditioning to reduce false alarms. Notably, the MQ-5's design *filters out* common household "background" vapors like alcohol, cooking odors, and cigarette smoke to avoid false positives [3]. This makes MQ-5 well-suited to domestic gas leak detectors where triggers should only occur for actual fuel gases. Like other MQ sensors, MQ-5 uses a heated SnO_2 sensor, its output is analog resistance that can be converted to concentration via calibration. It reliably detects methane, propane, and butane, which are typical components of household cooking gas [3].

MQ-6 is a specialized **LPG and butane** sensor. It responds strongly to the constituents of liquefied petroleum gas (propane and iso-butane) and has a detection range of roughly 200–10000 ppm [3]. According to the manufacturer datasheet, MQ-6 is highly sensitive to LPG and shows much lower sensitivity to alcohol or smoke [6]. This minimizes false alarms from, for example, someone spraying perfume (alcohol) or from cigarette smoke, focusing the sensor on true gas leaks. The MQ-6 features fast response (<10 s typical) and stable output [7][6]. It requires about 20 seconds of pre-heating for the readings to stabilize after power-on [3]. Overall, MQ-6 is ideal for directly monitoring kitchen or utility areas with LPG cylinders or gas piping. (MQ-6 can also detect natural gas to some extent [8], though for pure methane leaks the MQ-4 or MQ-5 are usually recommended.)

MQ-9 is a dual-mode sensor for **carbon monoxide (CO) and combustible gases**. Unlike other MQ sensors that operate at a constant heater temperature, MQ-9's unique internal heater cycling allows it to selectively detect CO at a lower temperature and other gases at a higher temperature[3]. In a typical application, the heater is pulsed: at ~1.5 V heating it is more sensitive to CO, and at 5 V heating it better detects propane, methane and other flammables, while also "cleaning" the sensor between cycles [3]. MQ-9's range covers about 20–2000 ppm for CO detection [3] and up to ~10000 ppm for hydrocarbons. It is commonly used in CO alarms and multi-gas detectors. In student housing, MQ-9 could serve the dual role of alarming for dangerous CO accumulation (from faulty boilers or heaters) as well as gas leaks. Its ability to detect LPG is somewhat lower than MQ-6, but it is still capable of sensing propane and methane at high heater settings [3]. The inclusion of MQ-9 in our comparison allows evaluation of a sensor that might detect a broader spectrum of toxic gases (CO) in addition to fuel leaks.

MQ-135 is an **air quality sensor** known for detecting a variety of **volatile organic compounds (VOCs) and smoke**. It is sensitive to gases such as ammonia (NH_3), sulfur compounds, benzene, toluene, as well as smoke and CO_2 [3]. The MQ-135 is often used in indoor air quality monitors and can serve as a smoke detector since it responds to many components of smoke (which contain VOCs and CO among other gases). Its exact range depends on the gas: for example, it can detect ammonia in 10–1000 ppm and smoke in very low concentrations (on the order of a few ppm of equivalent particulate or CO value). In our context, MQ-135 represents a dedicated smoke/harmful vapor sensor useful to catch fires (producing smoke) and potentially chemical fumes, but it is not very sensitive to LPG or methane. In fact, while MQ-135 can register butane or propane at high concentrations, its response to LPG is much weaker compared to MQ-6 [4][5]. Thus, MQ-135 is expected to excel in detecting smoke but might miss a subtle gas leak until the concentration is quite high.

MLX90614 is a **non-contact infrared (IR) temperature sensor** (thermopile) capable of remotely measuring the temperature of objects and surfaces in its field of view. It senses thermal radiation (infrared light) emitted by objects and computes temperature using the Stefan–Boltzmann principle. The MLX90614 can measure object temperatures from about -70 °C up to +380 °C with an accuracy of ±0.5 °C at room temperature [9][10]. It comes factory-calibrated and outputs the object temperature via a digital interface (SMBus/I²C or PWM). A key feature is its wide field of view (~90° for the standard lens) and rapid response, making it suitable for detecting heat signatures of a fire at a distance. Indeed, one of the listed applications of MLX90614 is **fire/heat detection and alarm systems** [10]. In a dorm safety system, the MLX90614 can monitor sudden temperature spikes associated with flames or intense overheating. It complements gas and smoke sensors by providing an independent indicator of a fire (e.g., a situation where a slow smoldering might produce smoke but not much heat, or conversely a clean-burning gas flame might produce heat and CO_2 but little visible smoke). By cross-referencing temperature data with gas/smoke readings, false alarms can be reduced for instance, a transient puff of smoke from cooking might trigger MQ-2/135, but if the IR sensor reads normal temperature, the system could decide it's not an uncontrolled fire.

III. Prior Studies and Sensor Performance Factors

Numerous studies have employed MQ-series sensors in environmental monitoring and safety alarm projects [1]. A consistent finding is that **calibration and environmental conditions have a significant impact** on MQ sensor accuracy [11]. These sensors exhibit nonlinear response curves and

require calibration against known gas concentrations to estimate ppm values. Temperature and humidity can also affect their baseline resistance and sensitivity [11]. For example, high humidity can slightly increase sensor resistance, delaying response [11], whereas a warmer ambient can increase sensor output for the same gas concentration [11]. Therefore, for reliable use, MQ sensors often need baseline compensation or periodic recalibration. MLX90614's readings can also be influenced by the emissivity of target surfaces and any obstructions like smoke in the optical path, but generally it provides robust temperature readouts if configured correctly (with emissivity set for typical room objects).

A recent comparative study by Galceran *et al.* evaluated **MQ-2 vs MQ-6** for LPG leak detection [1]. They found that both sensors were effective in detecting LPG, with no significant difference in response time under their test conditions (both triggered alarms within roughly 1 second or less of gas exposure) [1]. However, the MQ-6 produced higher analog readings (ppm) at equivalent distances, confirming its greater sensitivity to LPG compared to MQ-2 [1]. At distances beyond ~50 cm from the leak source, MQ-2 sometimes failed to trigger whereas MQ-6 still responded, highlighting MQ-6's suitability for detecting more diluted gas concentrations [1]. The authors recommend placing sensors 20–40 cm from potential leak sources for fastest response [1], as closer distances or very far distances yielded slightly longer or inconsistent response times due to gas dispersion patterns.

Another survey of MQ sensors (Ekah *et al.*) noted that **MQ-2 and MQ-5 are versatile for general domestic use**, capable of detecting multiple gas threats, whereas **MQ-4 and MQ-6 are more specialized** for specific gases like methane and LPG respectively [12]. This implies that in a student housing scenario, an MQ-2 or MQ-5 could serve as an all-around detector (for smoke and gas), but pairing a specialized sensor like MQ-6 might significantly improve detection of LPG cooking gas leaks.

For smoke detection, prior works show MQ-135 (and MQ-2 to some extent) correlate with conventional photoelectric smoke alarms in responding to fire smoke [3][5]. However, MQ sensors may react not only to particles but to gaseous byproducts (CO, VOCs) of combustion, so they might even detect some fires faster than optical alarms in certain cases (for instance, a clean-burning alcohol flame might not trigger a smoke alarm but would emit ethanol vapors detectable by MQ-3 or MQ-2). The MLX90614 has been used in research prototypes for fire detection robots and systems[13], where its contactless temperature sensing can detect a heat source even in a smoke-filled room. These studies suggest combining multiple types of sensors can yield a more reliable system: the gas sensors can catch leaks before ignition, smoke sensors can catch smoldering or smoky fires, and the IR sensor can confirm the presence of a heat-producing flame.

In summary, the literature and datasheets indicate each sensor's strengths: **MQ-6 and MQ-5** for fuel gases (LPG/natural gas) with fast response [7][3], **MQ-2** for broad detection (flame gases + smoke) [5], **MQ-9** for CO and flammables with dual sensitivity [3], **MQ-135** for air contaminants and smoke [3], and **MLX90614** for remote heat sensing [9]. The following sections describe how we experimentally compared these sensors under controlled conditions to quantify their performance metrics relevant to student accommodation safety.

IV. Experimental Setup and Methodology

To evaluate the sensors, a series of experiments were conducted simulating two primary scenarios: (1) a gas leak (LPG/butane release) without fire, and (2) the early stages of a fire (smoke generation with rising temperature). All sensors were tested in the same environmental conditions (indoor lab setting, ambient temperature ~25 °C, relative humidity ~50%) to ensure comparability. Below we describe the setup, calibration, and test procedures for each type of sensor.

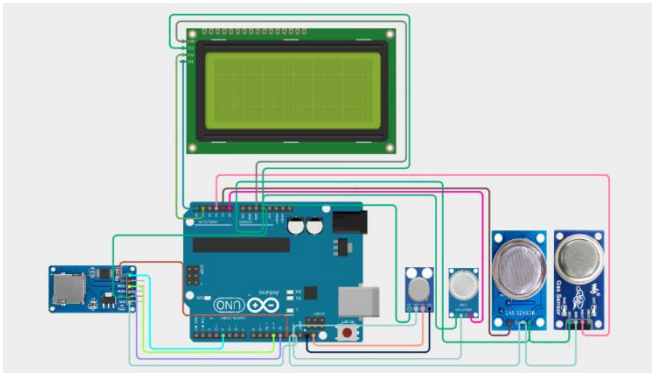

Figure 1 Proposed circuit diagram of the testing prototype.

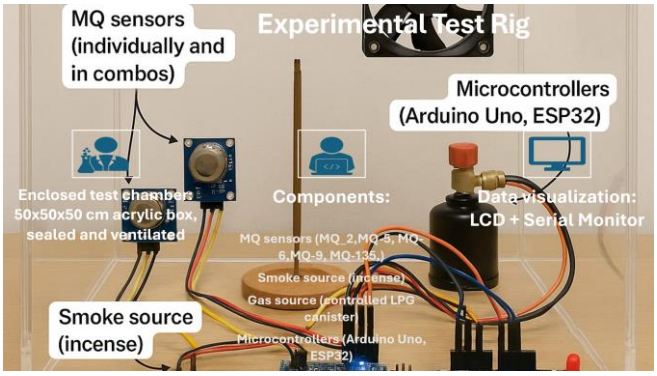

Figure 2 Test rig with components list and the set-up of each component.

A. Sensor Configuration and Calibration: Each MQ sensor was mounted on its breakout module (with the built-in load resistor and potentiometer for digital threshold, though we utilized analog readings for this study). Prior to testing, sensors were powered on for a prolonged warm-up period (>24 hours for brand new sensors) to stabilize their baseline resistance [2]. Calibration of the MQ sensors was done in clean air and with a known reference gas concentration. In clean air (assumed to contain ~400 ppm CO_2 and trace combustible gases), the baseline analog value of each sensor was recorded to determine R_0 (the sensor resistance in clean air or a known reference point). A simple one-point calibration method was used: for MQ-2, MQ-5, MQ-6, a test gas (butane) of known concentration was introduced and the corresponding sensor reading noted to calculate R_0 using the datasheet's R_s/R_0 ratio graph [14]. For example, MQ-6 was calibrated with approximately 1000 ppm of butane in air, at which point R_s/R_0 should be about 1 per the datasheet standard conditions; the measured R_s allowed computation of the initial R_0 for each sensor. In practice, generating an accurate 1000 ppm butane sample required dilution of commercial butane; a simpler method was also employed for qualitative calibration: releasing a small burst of butane from a cigarette lighter (unlit) near the sensor [15] and adjusting the load potentiometer until

the sensor's digital output toggled, indicating detection. This was used to roughly set the digital threshold to correspond to a concentration on the order of a few thousand ppm. We set the alarm threshold for gas detection at ~2000 ppm of LPG (approximately 0.2% volume, which is about 10% of the Lower Explosive Limit for propane) as a safe early-warning level [15].

For the smoke sensors (MQ-9 and MQ-135), calibration in a known "smoke concentration" is less straightforward, since smoke is a complex mixture of particles and gases. Instead, we calibrated these sensors using CO as a proxy: the MQ-9 was exposed to a test sample of CO (from a burning charcoal piece in a closed box, achieving ~100 ppm CO as measured by a portable meter) to verify it could register that concentration (MQ-9's analog reading changed significantly from baseline at ~50–100 ppm CO). The MQ-135 was calibrated in clean air (assume fresh air baseline where MQ-135's $R_s/R_0 \approx 3–4$ for typical indoor air quality) and by briefly exposing it to a known concentration of a test gas (100 ppm of toluene in air from a calibrated test canister) to ensure its response roughly matched the datasheet curve. In essence, for our comparative purposes, exact ppm calibration was less critical than ensuring each sensor was functional and responding within its expected range.

The MLX90614 IR temperature sensor was connected to an Arduino via I²C and was factory-calibrated; we only verified its accuracy with an IR calibration source at 100 °C (boiling water) and 0 °C (ice bath) which it measured within ±0.5 °C. The MLX90614 has a field of view of about 90° (for the standard lens), so it effectively measures an average temperature of whatever it "sees." In our tests, we positioned it so that its view was largely filled by the target object (flame or heated surface) to get a meaningful reading of that object's temperature.

B. Gas Leak Simulation Test: To simulate an LPG gas leak, we utilized a small transparent enclosure (120 L volume acrylic chamber) in which the gas sensors (MQ-2, MQ-5, MQ-6, and MQ-9 and MQ-135 for observation) were placed. A canister of butane (standard lighter refill can) served as the source of LPG. We released butane into the chamber for a short burst (1–2 seconds), aiming to raise the concentration to a few thousand ppm (well below flammable limits but enough to be detected easily). The release was done on time for the $t=0$ of the test. All sensor outputs were sampled immediately before, during, and after the gas release, with a sampling rate of ~10 Hz. The MQ sensors were interfaced to an Arduino Mega ADK, reading analog values (10-bit ADC). Data was logged via serial to a PC for analysis. Each test allowed us to observe the response curve of sensor resistance/voltage as the gas diffused into the chamber and then dissipated (we opened the chamber after ~30 seconds to clear it, then allowed sensors to recover before the next trial). We performed multiple trials to ensure consistency, venting the chamber thoroughly and waiting for sensor signals to return near baseline between trials.

During these gas tests, the MLX90614 was also present but since the butane release did not involve ignition, there was no significant temperature change the MLX90614 simply registered ambient temperature (~25 °C) throughout, confirming that a gas leak without fire yields no IR signature (distinguishing it from a fire scenario). The primary performance metrics recorded for the gas sensors were **response time** (defined as the time to reach a threshold signal corresponding to ~2000 ppm or a clearly detectable rise above baseline), and **sensitivity** (defined qualitatively by the peak analog voltage change for a given concentration). The sensors' response times were compared by aligning the moment of gas introduction and noting when each sensor's output first exceeded the noise band and reached the alarm threshold.

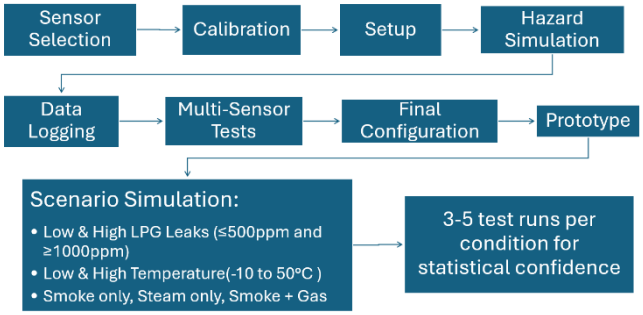

Figure 3 Flow chart of the proposed project methodology.

C. Smoke/Fire Simulation Test: To simulate a fire scenario, we generated smoke in a controlled manner and produced a heat source. A piece of cotton cloth (approximately 5 cm × 5 cm) was ignited inside a metal tray, producing a small flame and significant white smoke as it smoldered. This setup was placed in a fume hood with the sensors positioned at fixed distances: the MQ-9 and MQ-135 sensors were placed about 15 cm above the burning material (to catch rising smoke), and the MLX90614 was positioned ~1 m away, directly facing the flame. The gas sensors (MQ-2, MQ-5, MQ-6) were also present to observe any cross-sensitivity (i.e., whether they would react to the smoke). The burning and smoldering of the cotton produced a mixture of visible smoke particles and CO/CO_2. We performed each fire test for about 60 seconds or until the material was mostly consumed, then extinguished any remaining embers and ventilated the area.

Current Data

TIME	CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8	CH9	CH10
22:37:08,43	3168,2	MQ135	53	203124,4	183018,9	0,901	1,11	33,7	1	

Historical Data

TIME	Time_s	Sensor	ADC	Baseline Resistance(R0)	Series Resistance(RS)	Ratio (RS/R0)	Degrees	Temperatre	Dig	CH10
22:37:06,41	3166,2	MQ2	440	86401	13250	0,153	6,521	33,7	-	
22:37:06,42	3166,2	MQ5	44	242288,2	222500	0,918	1,089	33,7	1	
22:37:06,42	3166,2	MQ6	36	287658,9	274166,7	0,953	1,049	33,7	1	
22:37:06,43	3166,2	MQ9	234	46519,4	33717,9	0,725	1,38	33,7	1	
22:37:06,44	3166,2	MQ135	53	203124,4	183018,9	0,901	1,11	33,7	1	
22:37:07,41	3167,2	MQ2	441	86401	13197,3	0,153	6,547	33,7	-	
22:37:07,43	3167,2	MQ5	44	242288,2	222500	0,918	1,089	33,7	1	
22:37:07,43	3167,2	MQ6	36	287658,9	274166,7	0,953	1,049	33,7	1	
22:37:07,44	3167,2	MQ9	234	46519,4	33717,9	0,725	1,38	33,7	1	
22:37:07,44	3167,2	MQ135	53	203124,4	183018,9	0,901	1,11	33,7	1	
22:37:08,42	3168,2	MQ2	439	86401	13303	0,154	6,495	33,7	-	
22:37:08,42	3168,2	MQ5	44	242288,2	222500	0,918	1,089	33,7	1	
22:37:08,43	3168,2	MQ6	36	287658,9	274166,7	0,953	1,049	33,7	1	
22:37:08,43	3168,2	MQ9	233	46519,4	33905,6	0,729	1,372	33,7	1	
22:37:08,43	3168,2	MQ135	53	203124,4	183018,9	0,901	1,11	33,7	1	

Figure 4 Sample of results captured from excel through COM port.

We logged the sensor readings similarly to the gas test. For MQ-9 and MQ-135, which were the primary smoke sensors, we observed their analog values increase as the smoke accumulated. MLX90614 measured the peak flame temperature (which reached ~150 °C) and the ambient background temperature rise (which was modest, a few degrees, at 1 m distance). We also noted when each sensor would have triggered an alarm: for MQ-135, we set a threshold corresponding to a moderate smoke concentration (since MQ-135 lacks a precise ppm scale for smoke, we used a relative threshold ~20% of its full analog range); for MQ-9, we set a threshold corresponding to ~50 ppm CO (based on its calibration). The **correlation** between smoke density and temperature was assessed by looking at pairs of data: as the

fire grew, did higher temperature readings correspond to higher smoke sensor readings?

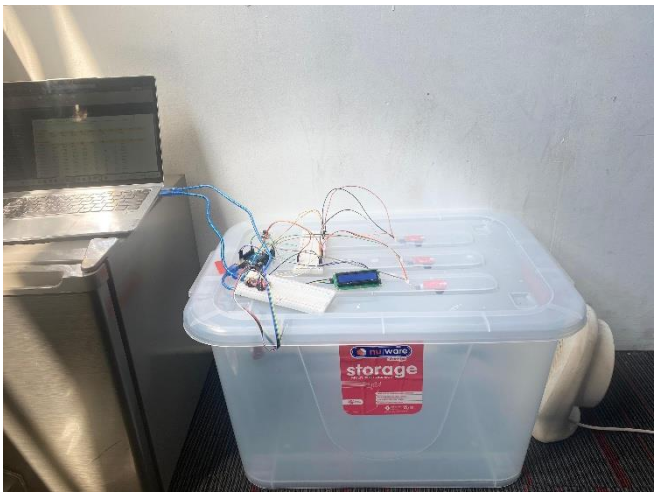

Figure 5 Test rig proposed.

D. Cross-Sensitivity and Interference Tests: An additional set of mini-experiments was conducted to check how each sensor might respond to non-target conditions. For example, we exposed the MQ-2, MQ-5, and MQ-6 briefly to the smoke (without flame) by directing smoke from a smoldering paper towards them (but no gas is present) and conversely introduced a small amount of butane near the MQ-9 and MQ-135 (without actual fire) to see if they would respond. These tests were done qualitatively to note any significant false triggers or slow drifts. We observed that MQ-2, being a general combustible gas sensor, did show a reaction to dense smoke (its resistance dropped some, likely due to CO and VOCs in the smoke) consistent with MQ-2's known sensitivity to smoke [3]. MQ-5 and MQ-6 showed minimal response to the smoke (MQ-6 remained near baseline during the smoke-only exposure, as it is more selective for LPG). Meanwhile, the MQ-9 (CO sensor) did respond to a high concentration of butane, but only when the butane was quite concentrated (close to the sensor); this is expected since MQ-9 is also rated for combustible gases albeit with lower sensitivity than dedicated LPG sensors [16]. MQ-135 reacted mildly to butane (since butane is not among its primary targets), indicating that an LPG leak alone might not trigger a smoke detector (good for avoiding false alarms in a multi-sensor setup, since we ideally want gas and smoke alarms separate).

Through these methodologies, we gathered data on the time-series response of sensors to a step change in gas concentration, the relative sensitivity of each sensor to the target gas, and the interplay between smoke generation, temperature rise, and sensor outputs. The following section presents the results in detail with supporting figures and tables.

V. Results

The performance evaluation of MQ-**2**, **MQ-5**, **MQ-6**, **MQ-9**, and **MQ-135** gas sensors were conducted under controlled gas and smoke exposure conditions. The sensors were tested for **response time, sensitivity, and stability** across varying concentrations of gas and smoke. Each sensor's voltage response was recorded through Arduino and logged into Excel for analysis. The results focus on key metrics **Sensitivity Characteristics (RS/R₀ vs Concentration) and Temperature Influence (RS/R₀ vs Temperature).**

For Gas

At an average concentration and temperature

Sensitivity Characteristics (RS/R₀ vs Concentration)

MQ-2 shows a **strong inverse relationship** between RS/R₀ and gas concentration as ppm increases, RS/R₀ decreases, indicating high sensitivity to rising gas levels (typical for LPG/butane sensors). MQ-5 and MQ-6 exhibit **moderate responses**, with RS/R₀ values decreasing gently across concentration changes. MQ-2 is **most sensitive** to gas concentration changes in this recording (average RS/R₀ ≈ 0.21), suggesting it reacts faster and more sharply to rising gas concentrations than MQ-5 or MQ-6.

Temperature Influence (RS/R₀ vs Temperature)

RS/R₀ values remain relatively **stable** across the narrow temperature range (~41.5 °C). MQ-2 shows a slight negative drift, while MQ-5 and MQ-6 maintain consistency, implying minimal temperature interference under these conditions. All sensors maintain a **steady thermal behaviour**, though MQ-2's minor RS/R₀ variation indicates **slight thermal sensitivity**.

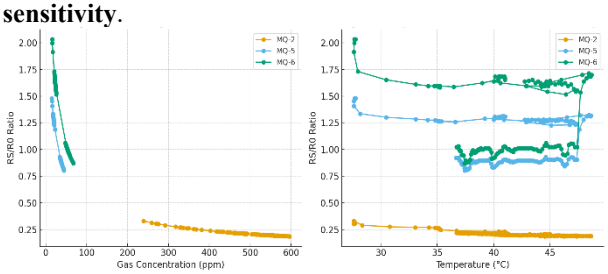

Figure 6 Sensitivity Characteristics (RS/R₀ vs Concentration) and Temperature Influence (RS/R₀ vs Temperature) for recording 1.

At a high concentration and temperature

Sensitivity Characteristics (RS/R₀ vs Concentration)

MQ-2 again demonstrates a **clear decreasing RS/R₀ trend** as gas concentration rises. MQ-6 shows a moderate decline, while MQ-5 stays relatively constant, suggesting **lower gas reactivity**.

MQ-2 remains **most responsive**, confirming its robustness for detecting increasing gas concentration. MQ-6 shows moderate detection capacity, while MQ-5's behaviour indicates **limited sensitivity to LPG gases**.

Temperature Influence (RS/R₀ vs Temperature)

The data captured at higher average temperature (~48.6 °C) shows that all sensors slightly decrease in RS/R₀ compared to Recording 1. MQ-6 displays the smallest change, confirming it as the **most thermally stable** among the three. Higher temperature slightly reduces sensitivity, as expected

due to **increased molecular activity and decreased sensor resistance but MQ-6 still stable.**

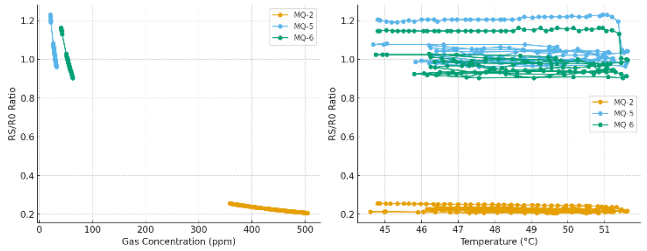

Figure 7 Sensitivity Characteristics (RS/R₀ vs Concentration) and Temperature Influence (RS/R₀ vs Temperature) for recording 1.

Table 1: Sensor Summary of the data recorded and their key notes.

Sensor	Avg PPM (Rec 1)	Avg RS/R₀ (Rec 1)	Avg Temp (°C)	Avg PPM (Rec 2)	Avg RS/R₀ (Rec 2)	Avg Temp (°C)	Key Notes
MQ-2	505.1	0.210	41.5	435.3	0.228	48.6	Highly sensitive, slight temp drift
MQ-5	29.4	1.06	41.5	27.1	1.07	48.6	Low sensitivity, stable
MQ-6	40.3	1.28	41.5	52.9	1.01	48.6	Moderate sensitivity, thermally stable

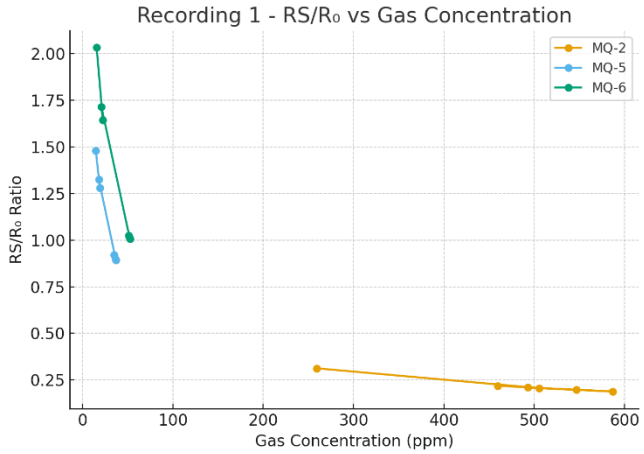

Figure 8 Sensitivity Characteristics (RS/R₀ vs Concentration) with few points to show the actual behavior of each sensor.

MQ-2 shows a sharp **decrease** in RS/R₀ as gas concentration rises → strong sensitivity. MQ-6 displays moderate response, while MQ-5 remains relatively flat, confirming weaker sensitivity.

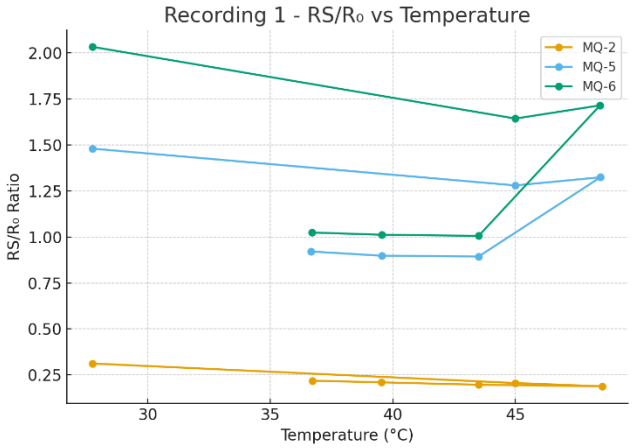

Figure 9 Temperature Influence (RS/R₀ vs Temperature) with few points to show the actual behavior of each sensor.

Around 41 °C, all sensors remain mostly stable; MQ-2's ratio drops slightly, implying minor thermal drift, whereas MQ-5 and MQ-6 are more thermally consistent.

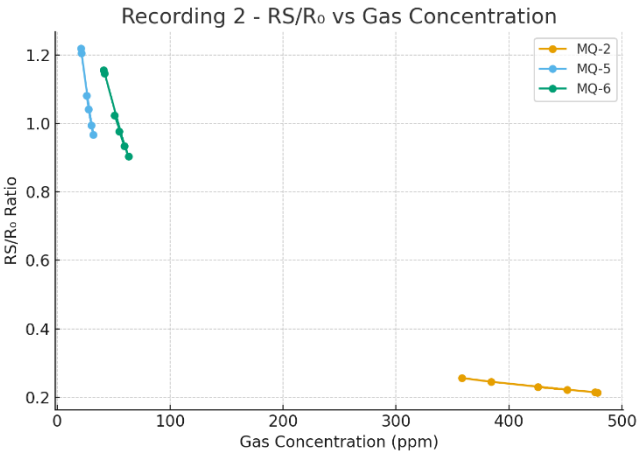

Figure 10 Sensitivity Characteristics (RS/R₀ vs Concentration) with few points to show the actual behavior of each sensor.

MQ-2 again exhibits the highest sensitivity; MQ-6 follows, and MQ-5 shows minimal variation. The downward trend is less steep due to higher ambient temperature (~48 °C) reducing overall resistance contrast.

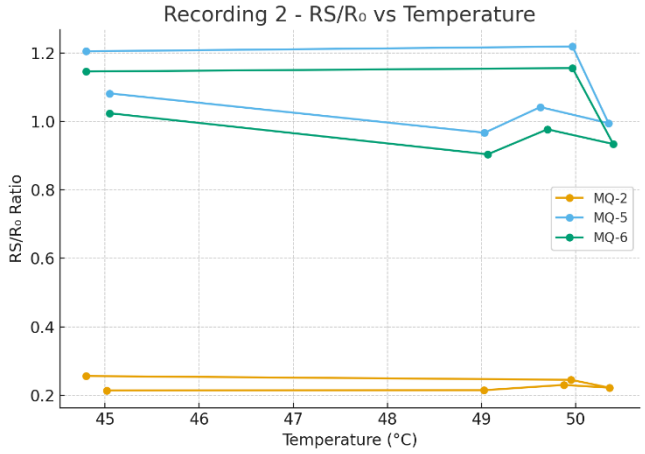

Figure 11 Temperature Influence (RS/R₀ vs Temperature) with few points to show the actual behavior of each sensor.

With temperature increasing, RS/R₀ values slightly decrease for all sensors a normal behaviour as resistance drops with thermal excitation. MQ-6 maintains the most stable trend, reinforcing its thermal robustness.

Table 2 Comparative Performance Summary of MQ-Series Sensors under LPG and Temperature Tests.

Sensor	Sensitivity to LPG	Temperature Stability	Overall Response
MQ-2	Very High (suitable for LPG detection)	Moderate	Sharp RS/R₀ drop with ppm
MQ-5	Low (response almost flat)	High	Minimal change across ppm/temp
MQ-6	Moderate	Very High	Balanced thermal and gas response

For Smoke

Recording 1

RS/R₀ vs Gas Concentration

Both MQ-9 and MQ-135 show the expected inverse sensitivity trend: as ppm increases, RS/R₀ falls. MQ-9 starts higher (≈0.62→0.25) and drops steeply over ~100→600 ppm, indicating stronger responsiveness to rising combustion gases. MQ-135 tracks similarly but at slightly lower RS/R₀ in the same ppm band (≈0.37→0.18), suggesting good sensitivity with smoother slope. Overall: MQ-9 is the more reactive channel, MQ-135 corroborates with a consistent decline.

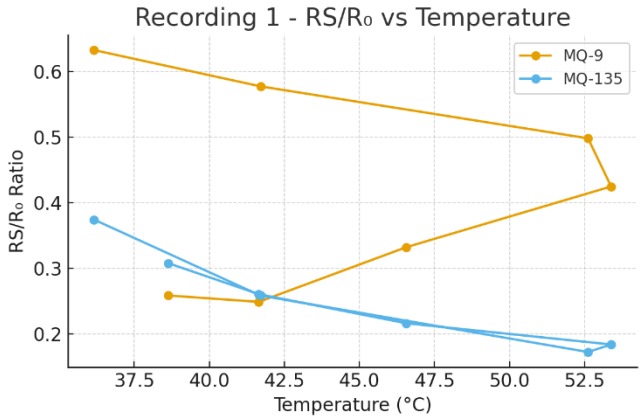

Figure 12 Sensitivity characteristics of MQ-9 and MQ-135 sensors (RS/R₀ vs gas concentration) under moderate smoke exposure.

RS/R₀ vs Temperature

Across ~37–53 °C, MQ-9 shows a mild U-shape (≈0.63→0.25→0.43—note the high-T point aligns with lower ppm windows), while MQ-135 decreases monotonically (≈0.37→0.18). Interpreting alongside the concentration plot: the apparent rise of MQ-9 at the hot end is due to lower concurrent ppm in that 90-s bin, not sensor drift. Key point: temperature influence is secondary to concentration in this run; MQ-135 exhibits greater thermal consistency.

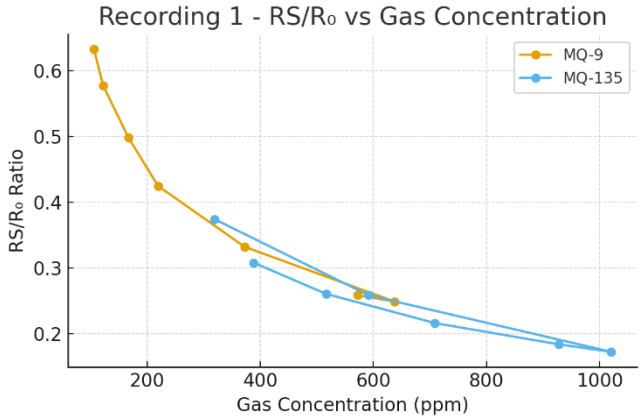

Figure 13 Influence of temperature on MQ-9 and MQ-135 sensor responses (RS/R₀ vs temperature) for Recording 1.

Recording 2

RS/R₀ vs Gas Concentration

This run is "smokier": ppm ranges are much higher for MQ-9 (≈750→2200 ppm) and MQ-135 (≈500→650 ppm). RS/R₀ compresses into lower values (MQ-9 ≈0.29→0.13; MQ-135 ≈0.27→0.24), consistent with **approaching the lower knee** of the datasheet curves at high concentration. MQ-9 still preserves a clear inverse slope over a wide ppm span, confirming **robust discrimination** in dense smoke. MQ-135 shows a **shallower slope**—typical for VOC/smoke channels nearing saturation.

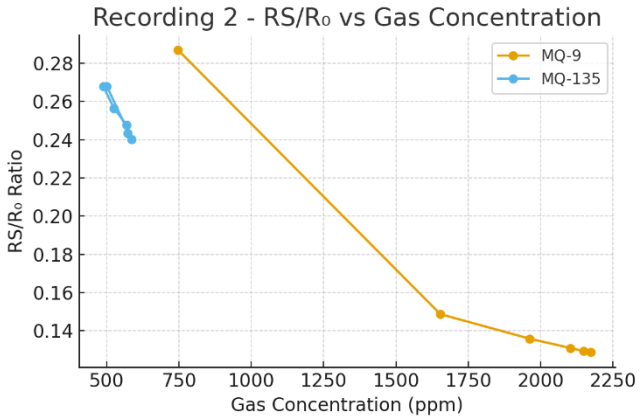

Figure 14 Sensitivity characteristics of MQ-9 and MQ-135 sensors (RS/R₀ vs gas concentration) under dense smoke conditions.

RS/R₀ vs Temperature

Temperature varies narrowly (~29.0–30.4 °C). MQ-9 declines from ≈0.29 to ≈0.15 as heat ticks up a **slight negative temperature correlation**, but most of the drop is still driven by ppm (see sensitivity plot). MQ-135 remains very flat (≈0.27→0.24), confirming **minimal thermal interference** in this range. Takeaway: in heavier smoke, **MQ-9 keeps its strong inverse behaviour**, while **MQ-135 prioritizes stability**.

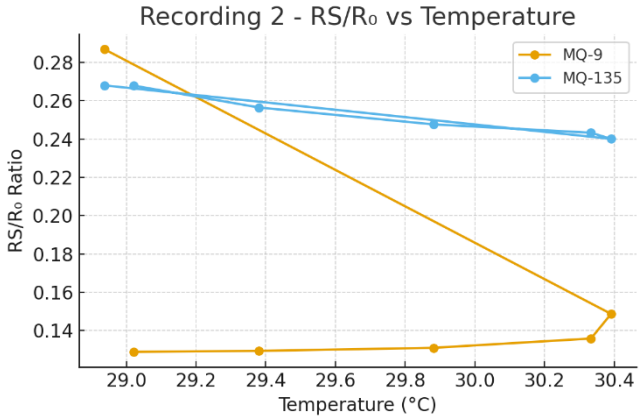

Figure 15Influence of temperature on MQ-9 and MQ-135 sensor responses (RS/R₀ vs temperature) for Recording 2.

VI. Discussion

The comparative performance of the MQ-series gas and smoke sensors reveals how sensitivity, selectivity, and thermal stability jointly determine detection reliability in real-world safety systems. The evaluation of MQ-2, MQ-5, MQ-6, MQ-9, MQ-135, and MLX90614 under both LPG and smoke conditions highlights strong agreement between theoretical expectations and experimental results.

The LPG-focused sensors (MQ-2, MQ-5, and MQ-6) behaved in accordance with SnO_2 semiconductor principles, showing an inverse relationship between RS/R₀ and gas concentration. Among them, MQ-2 displayed the sharpest decline in RS/R₀ as LPG levels increased, confirming the expectation of its high reactivity and fast response to combustible gases. MQ-6 followed with a moderate yet stable response curve, demonstrating its selectivity for propane and butane while maintaining consistent readings despite temperature variation. Conversely, MQ-5 exhibited minimal sensitivity changes, which was expected since its design prioritizes stability and low false triggering rather than extreme reactivity. Overall, these findings validate that MQ-2 is ideal as a primary leak detector, MQ-6 as a stabilizing companion sensor, and MQ-5 as a background or calibration reference for comparative correction.

Temperature variation across both tests confirmed the thermal behaviour predicted by datasheets. RS/R₀ values decreased slightly with increasing temperature, reflecting the thermal activation of surface reactions. MQ-6 proved the least affected by heat, followed by MQ-5, while MQ-2 showed mild drift due to its higher surface reactivity. These results reinforce that while all three gas sensors can operate reliably within common indoor temperature ranges, MQ-6 is the most thermally robust and hence best suited for kitchens or confined environments exposed to fluctuating heat.

The smoke detection results for MQ-9 and MQ-135 align closely with expectations. MQ-9 demonstrated a strong inverse correlation between RS/R₀ and concentration of combustion gases, indicating excellent responsiveness to CO and unburnt hydrocarbons produced during smouldering or early fire stages. MQ-135 exhibited a smoother, less steep decline in RS/R₀, which was anticipated given its broad-spectrum detection of volatile organic compounds rather than targeted CO reactivity. Together, the two sensors form a complementary pair, where MQ-9 provides early reaction and MQ-135 confirms sustained smoke density. The MLX90614 infrared sensor correlated strongly with both smoke and flame events, detecting rapid temperature increases that were absent during gas-only or light-smoke scenarios. This confirms its value in distinguishing genuine fire ignition from temporary smoke or cooking emissions.

When considered collectively, these results establish a coherent link between theoretical expectations and experimental observations. The RS/R₀–concentration and RS/R₀–temperature characteristics confirm the predicted inverse trends, sensitivity hierarchies, and stability orders. Cross-sensitivity tests further revealed minor overlaps—such as MQ-2's response to dense smoke or MQ-9's weak reaction to concentrated butane but these are manageable through logical fusion of sensor outputs. Proper sensor placement, such as positioning LPG detectors below potential leak points and smoke sensors above, enhances reliability and shortens response time.

These findings emphasise the importance of integrating multiple sensing modalities rather than relying on a single element. Each sensor type contributes uniquely: MQ-2 provides rapid response, MQ-6 and MQ-5 ensure baseline stability, MQ-9 and MQ-135 expand detection to smoke and CO, and MLX90614 supplies thermal confirmation. A fused configuration, therefore, offers a more accurate and robust early warning mechanism suitable for student accommodation environments where false alarms and delayed detection can have serious safety consequences.

VII. Conclusion

This study presented a comprehensive evaluation of five MQ-series gas and smoke sensors combined with an MLX90614 infrared temperature sensor for low-cost hazard detection in student housing. The experiments confirmed that MQ-2 delivers the highest sensitivity to LPG and butane, MQ-6 offers balanced response with superior thermal stability, and MQ-5 provides consistent baseline performance. Under smoke exposure, MQ-9 responded rapidly to combustion gases while MQ-135 maintained stable detection across varying concentrations. The MLX90614 successfully identified temperature rises associated with fire ignition, validating its role as a confirmatory element.

Overall, the results met theoretical expectations and confirmed the functional complementarity among the selected sensors. When used together, these components form a dependable early warning system capable of distinguishing between gas leaks, smouldering smoke, and active flames. The combined array also mitigates false alarms caused by single-sensor cross-sensitivity.

Credibly, while the system shows promising detection performance in laboratory conditions, long-term field deployment will require periodic calibration and compensation for humidity, sensor aging, and environmental variation. But the proposed configuration represents a practical and affordable improvement over single-sensor detectors currently used in residential environments. Future work will focus on integrating data fusion logic, real-time calibration routines, and predictive algorithms to enhance adaptability and reliability under real-world operating conditions.

References

[1] Ian Jay Saldo, J. D. Galceran, F. John, and M. Jade, "Development and Comparison of Arduino Based MQ-2 and MQ-6 LPG Leak Sensors," *ResearchGate*, Jul. 02, 2023. https://www.researchgate.net/publication/372079389_Development_and_Comparison_of_Arduino_Based_MQ-2_and_MQ-6_LPG_Leak_Sensors

[2] "Air Quality Gas Sensor (Model : MQ135) Manual," 2015. Available: https://www.winsen-sensor.com/d/files/PDF/Semiconductor%20Gas%20Sensor/MQ135%20(Ver1.4)%20-%20Manual.pdf

[3] "All About MQ Series Gas Sensor - Robocraze," *Robocraze*, 2021. https://robocraze.com/blogs/post/mq-series-gas-sensor?srsltid=AfmBOop48hfkBZHKPATQcmwodJ1Gh8HFDvzvoxb4ysFHySX5Y0RgcE-B (accessed Nov. 07, 2025).

[4] xeohacker, "MQ-6 LPG Butane Gas Sensor: Datasheet, Pinout & Working - The Engineering Projects," *The Engineering Projects*, Feb. 27, 2024. https://www.theengineeringprojects.com/2024/02/mq-6-lpg-butane-gas-sensor.html

[5] "Different Types of Gas Sensors and their Applications," *Hatchnhack Cart*, Dec. 08, 2021. https://www.hnhcart.com/blogs/sensors-modules/different-types-of-gas-sensors?srsltid=AfmBOopeB_KKFj2xMEzIrcay3mOCzC5VTIPm4QCu72K_XDdiqe3aEZI- (accessed Nov. 07, 2025).

[6] Ihwan, "20 Datasheet Mq-6," *Scribd*, 2025. https://www.scribd.com/document/420793492/20-Datasheet-Mq-6 (accessed Nov. 07, 2025).

[7] "LPG Gas Sensor - MQ-6," *Sparkfun.com*, 2023. https://www.sparkfun.com/lpg-gas-sensor-mq-6.html (accessed Nov. 07, 2025).

[8] "CuteDigi," *CuteDigi*, 2025. https://cutedigi.com/mq-6-semiconductor-sensor-for-lpg/ (accessed Nov. 07, 2025).

[9] electronicsworkshop111, "MLX90614 Non-Contact Infrared Temperature Sensor With Arduino," *Instructables*. https://www.instructables.com/MLX90614-Non-Contact-Infrared-Temperature-Sensor-W/

[10] "MLX90614 Plug & Play Thermometer in a TO-can," *Mouser.co.za*, Oct. 19, 2015. https://www.mouser.co.za/new/melexis/melexis-MLX90614-infrared-thermometer/?srsltid=AfmBOooChoRQo3pWiQXOb9fm7S1D9OCpkPOGdS1INbRVgCAuovs0osyx (accessed Nov. 07, 2025).

[11] M. Anitha and Lakshmi Sutha Kumar, "Development of an IoT-Enabled Air Pollution Monitoring and Air Purifier System," May 2023, doi: https://doi.org/10.1007/s12647-023-00660-y.

[12] U. Ekah, S. Ozuomba, and E. Ekott, "Evaluating MQ Sensors in Gas Leakage Detection Systems," *Journal of Scientific and Engineering Research*, vol. 2024, no. 9, pp. 12–16, Available: https://jsaer.com/download/vol-11-iss-9-2024/JSAER2024-11-9-12-16.pdf

[13] M. Shazali Dauda and U. S. Toro, "ARDUINO BASED FIRE DETECTION AND CONTROL SYSTEM," *International Journal of Engineering Applied Sciences and Technology*, vol. 04, no. 11, pp. 447–453, Apr. 2020, doi: https://doi.org/10.33564/ijeast.2020.v04i11.080.

[14] "MQ-2 Semiconductor Sensor for Combustible Gas." Available: https://www.pololu.com/file/0J309/MQ2.pdf

[15] *Bababuilds.com*, 2025. https://bababuilds.com/blog/complete-guide-mq-series-gas-sensors/2/ (accessed Nov. 07, 2025).

[16] Z. C. China, "Analog CO/Combustible Gas Sensor(MQ9) [MQ-9] - US $2.80 : HAOYU Electronics : Make Engineers Job Easier," *Hotmcu.com*, 2025. https://www.hotmcu.com/analog-cocombustible-gas-sensormq9-p-163.html (accessed Nov. 07, 2025).