

# 1. TITLE

**Title:** *IoT-Based Air Quality Monitoring System*

**Q1: What does IoT mean? Explain in detail.**

**Answer:**

Internet of Things (IoT) refers to a system where physical devices embedded with sensors, processing capability, and network connectivity collect data from their environment and transmit it over the internet for storage, analysis, and decision-making.

In this project, IoT involves sensors measuring air quality parameters, an ESP32 microcontroller for edge processing, Wi-Fi connectivity for data transmission, cloud storage using Firebase, and a web application for visualization and alerts.

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**Q2: Why did you choose IoT instead of a standalone system?**

**Answer:**

A standalone system only provides local information and limited functionality.

IoT enables real-time remote monitoring, historical data storage, predictive analytics, and scalability.

Since air quality issues are time-dependent and location-specific, IoT allows users to access data anytime, receive alerts instantly, and make informed decisions even when away from the monitored environment.

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**Q3: Why “Air Quality Monitoring”?**

**Answer:**

Air pollution and hazardous gas exposure are silent threats that often go unnoticed until serious health or safety issues occur.

Air quality directly affects respiratory health, safety, and overall well-being, especially in urban and domestic environments.

Monitoring air quality provides early detection, prevention, and awareness rather than reacting after damage has occurred.

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## 2. BACKGROUND OF THE STUDY

#### **Q4: What problem are you trying to solve?**

**Answer:**

The main problem is the lack of affordable, real-time, localized air quality monitoring systems at the household and small-scale level.

Existing systems are centralized, expensive, and inaccessible, leaving individuals unaware of pollution or gas leaks in their immediate environment.

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#### **Q5: Why is this problem important?**

**Answer:**

Air pollution contributes to respiratory diseases, cardiovascular problems, and fire hazards.

Gas leaks such as LPG and carbon monoxide are especially dangerous indoors and can lead to poisoning or explosions.

Early detection significantly reduces health risks, property damage, and loss of life.

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### **3. PROBLEM STATEMENT**

#### **Q6: Can you summarize your problem statement in one sentence?**

**Answer:**

There is no cost-effective, real-time, and accessible air quality monitoring solution for households and small environments, leading to delayed detection of pollution and gas-related hazards.

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#### **Q7: Why are existing systems not sufficient?**

**Answer:**

Existing systems are designed for regulatory monitoring, not individual safety.

They are expensive, sparsely deployed, and do not provide real-time alerts at the point of exposure.

This makes them unsuitable for domestic and small-scale applications.

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## 4. OBJECTIVES

**Q8: What is your main objective?**

**Answer:**

To design a scalable IoT-based air quality monitoring system with real-time detection, prediction, alerts, and safety actuation.

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**Q9: Are your objectives achievable within your project timeline?**

**Answer:**

Yes. The objectives are carefully scoped to match available resources, time, and technical complexity.

The system uses readily available sensors, open-source tools, and lightweight machine learning models suitable for a one-month data collection period.

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## 5. JUSTIFICATION

**Q10: Why should this project be approved?**

**Answer:**

The project addresses a real societal problem using affordable technology.

It combines IoT, cloud computing, and machine learning in a practical and implementable way.

The system is scalable, low-cost, and suitable for real-world deployment, making it both academically and socially relevant.

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**Q11: Who benefits from this system?**

**Answer:**

Households, small businesses, schools, healthcare facilities, and urban communities.

It also benefits researchers and policymakers by providing localized environmental data.

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## 6. SCOPE OF THE STUDY

**Q12: What does your project cover?**

**Answer:**

The project covers hardware integration, firmware development, cloud connectivity, web-based visualization, alert systems, and basic machine learning for prediction and anomaly detection.

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**Q13: What does your project NOT cover?**

**Answer:**

It does not cover nationwide monitoring, industrial-grade certification, or regulatory compliance testing.

The focus is on localized, household-level monitoring.

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## 7. LITERATURE REVIEW

**Q14: What gap did you identify in the literature?**

**Answer:**

Most systems focus on data collection without real-time alerts or predictive analytics.

Few systems integrate safety response mechanisms at the household level.

There is also limited accessibility in developing regions due to cost and infrastructure constraints.

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**Q15: How does your project address this gap?**

**Answer:**

By combining low-cost sensors, IoT connectivity, machine learning, and automated safety alerts in a single system designed specifically for localized environments.

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## 8. METHODOLOGY

### Q16: Why did you choose ESP32?

**Answer:**

ESP32 offers built-in Wi-Fi, sufficient processing power, low energy consumption, and multiple ADC channels.

It is cost-effective and well suited for IoT applications.

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### Q17: Why MQ sensors despite their limitations?

**Answer:**

MQ sensors are affordable, widely available, and suitable for trend detection rather than absolute precision.

Their limitations are mitigated through calibration, environmental compensation, and machine learning-based correction.

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### Q18: Why Firebase?

**Answer:**

Firebase provides real-time database functionality, easy IoT integration, scalability, and instant alert triggers, making it ideal for rapid prototyping and real-time applications.

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## 9. MACHINE LEARNING

### Q19: Why not deep learning?

**Answer:**

Deep learning requires large datasets and high computational resources.

Given the one-month data collection period and embedded system constraints, classical ML models provide better interpretability, efficiency, and reliability.

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### **Q20: Why Isolation Forest for anomaly detection?**

#### **Answer:**

Isolation Forest works well with unlabeled data, is computationally efficient, and effectively detects rare abnormal events such as gas leaks or sudden pollution spikes.

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## **10. TESTING & EVALUATION**

### **Q21: How will you test your system?**

#### **Answer:**

Through controlled testing using simulated gas sources and real-world testing in domestic environments.

Metrics include sensor accuracy, alert latency, data transmission reliability, and usability.

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## **11. ETHICAL & SAFETY ISSUES**

### **Q22: Are there any ethical concerns?**

#### **Answer:**

No personal data is collected.

Gas testing is conducted safely in controlled environments.

The system is designed to enhance safety, not expose users to risk.

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## **12. EXPECTED OUTCOMES**

### **Q23: What is the key contribution of your project?**

#### **Answer:**

A low-cost, scalable, IoT-based system that provides real-time monitoring, predictive analytics, and safety alerts for localized air quality management.

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# 13. WORK PLAN & BUDGET

**Q24: Is your budget realistic?**

**Answer:**

Yes. All components are locally available, cost-effective, and justified based on system requirements.

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## FINAL DEFENSE TIP (VERY IMPORTANT)

If you forget something, say:

*“Based on the project scope and available resources, this approach provides the best balance between performance, cost, and feasibility.”*

That sentence saves lives in defenses 😊

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### 1 KILLER OPENING STATEMENT (≈60 seconds)

Use this to **start your presentation or defense**:

*Good morning members of the panel. My name is Joshua Muthenya Wambua, and my project is titled “An IoT-Based Air Quality Monitoring System.”*

*Air pollution and hazardous gas exposure remain silent but serious threats in both urban and domestic environments. Most existing monitoring systems are centralized, expensive, and inaccessible to individuals at the household level. As a result, dangerous conditions such as carbon monoxide buildup or gas leaks are often detected too late.*

*This project proposes a low-cost IoT-based system that continuously monitors air quality parameters such as particulate matter, carbon monoxide, LPG, temperature, and humidity. The system uses an ESP32 microcontroller to collect and process sensor data, transmits it to a cloud platform for real-time visualization, and applies machine learning techniques to predict pollution trends and detect anomalies.*

*The aim is to provide an affordable, scalable, and real-time solution that enhances environmental awareness, safety, and early hazard detection at the local level.*

💡 **Why this works:**

- Clear problem
  - Clear solution
  - Clear contribution
  - No overpromising
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## 2 RAPID-FIRE MOCK DEFENSE (KEY QUESTIONS + MODEL ANSWERS)

These are **short, sharp questions** examiners love.

### **Q1: Why did you choose this topic?**

**Answer:**

Because air quality directly affects health and safety, yet most people have no access to real-time monitoring. This project addresses that gap using affordable and scalable technology.

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### **Q2: What is new or unique about your project?**

**Answer:**

The integration of low-cost sensors, real-time IoT connectivity, predictive analytics, and a safety response mechanism in a system designed specifically for household and localized environments.

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### **Q3: Is this a hardware project or a software project?**

**Answer:**

It is a hybrid system that integrates hardware sensing, embedded firmware, cloud software, web applications, and machine learning analytics.

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### **Q4: Why not use government air quality data instead?**

**Answer:**

Government data is usually centralized, delayed, and not location-specific. My system provides real-time, point-of-exposure monitoring.

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## Q5: What happens if the internet fails?

### Answer:

The system performs threshold-based detection locally at the edge device, so alerts and safety responses still function even without cloud connectivity.

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## 3 RED-FLAG QUESTIONS EXAMINERS LOVE (AND HOW TO SURVIVE THEM)

These questions are **designed to shake you**. Don't panic.

### ► Q1: Are MQ sensors accurate enough for serious monitoring?

#### Safe Answer:

MQ sensors are not reference-grade, but they are suitable for trend detection and early warning. Accuracy limitations are mitigated through calibration, environmental compensation, and machine learning correction.

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### ► Q2: Isn't machine learning overkill for this project?

#### Safe Answer:

Machine learning is used selectively to improve prediction and anomaly detection, not as a replacement for basic threshold logic. The models are lightweight and appropriate for the dataset size.

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### ► Q3: What if your system gives false alarms?

#### Safe Answer:

Thresholds are carefully calibrated, and anomalies are cross-validated using multiple sensors and time-based analysis to reduce false positives.

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### ► Q4: Can this system be deployed commercially?

#### Safe Answer:

The prototype demonstrates technical feasibility. Commercial deployment would require regulatory certification, long-term calibration, and durability testing, which are outside the project scope.

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### ► Q5: What is the main limitation of your project?

#### Best Answer (shows maturity):

The use of low-cost sensors limits absolute accuracy, but the system prioritizes early detection, affordability, and accessibility over laboratory-grade precision.

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#### 4 CLOSING STATEMENT (30–40 seconds)

Use this when they say “**Thank you**” or “**Any final remarks?**”

*In conclusion, this project demonstrates that effective air quality monitoring does not have to be expensive or centralized. By combining low-cost sensors, IoT connectivity, cloud computing, and machine learning, the system provides real-time monitoring, early warnings, and predictive insights at the local level.*

*The project is practical, scalable, and relevant to current public health and safety challenges, especially in resource-limited environments. I believe this work provides a strong foundation for further research and real-world deployment. Thank you.*

okay what are these diseases instead of just mentioning diseases

Good question — this is **exactly** how examiners think.

They don’t want vague words like “*diseases*”; they want **specific, defensible examples**.

Here’s how I would answer **clearly and confidently** in a defense:

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#### Answer (Defense-ready):

When I refer to diseases, I am specifically talking about **respiratory and cardiovascular conditions** that have been strongly linked to poor air quality.

Fine particulate matter such as **PM2.5** penetrates deep into the lungs and bloodstream and is associated with **asthma, chronic bronchitis, chronic obstructive pulmonary disease (COPD), and reduced lung function**.

Long-term exposure also increases the risk of **heart disease, hypertension, and stroke**.

Carbon monoxide exposure reduces oxygen delivery in the body and can cause **headaches, dizziness, nausea, loss of consciousness**, and in severe cases **fatal poisoning**.

Additionally, exposure to smoke and toxic gases can aggravate **allergies, lung infections**, and increase vulnerability in children, the elderly, and people with pre-existing conditions.

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### Shorter version (if they cut you off):

Mainly asthma, chronic bronchitis, COPD, cardiovascular diseases, and carbon monoxide poisoning.

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### Why this answer works

- You named **specific diseases** ✓
- You linked them to **specific pollutants** ✓
- You didn't exaggerate ✓
- You stayed within engineering scope ✓

Ask the **next question** — push harder if you want.

carboxyhaemoglobine

Excellent — that's a **very sharp examiner-level keyword**.

Here's how to answer it **precisely and confidently**, without drifting into medical overkill.

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### Answer (Defense-ready):

**Carboxyhaemoglobin** is a compound formed when **carbon monoxide (CO)** binds with **haemoglobin** in the blood.

Carbon monoxide has a much higher affinity for haemoglobin than oxygen—about **200 to 250 times greater**—which means it displaces oxygen and reduces the blood's oxygen-carrying capacity.

As carboxyhaemoglobin levels increase, body tissues experience **hypoxia**, leading to symptoms such as headache, dizziness, fatigue, confusion, and in severe cases loss of consciousness or death.

This is why carbon monoxide is particularly dangerous—it is colorless, odorless, and toxic even at relatively low concentrations.

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**If the panel asks: “Why is this relevant to your project?”**

My system monitors carbon monoxide levels to provide early detection and alerts before carboxyhaemoglobin levels in the body can rise to dangerous levels.

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### **One-line killer response (if interrupted):**

Carbon monoxide forms carboxyhaemoglobin, which prevents oxygen delivery to tissues, making early CO detection critical.

okay lets discuss the models dicused,ml libraries that can be used,python libraries,the datasets and the training procedure

Perfect — now you're asking **core technical-defense questions**.

I'll answer as if I'm defending in front of **EEE + CS examiners**, so the depth is *just right* (not shallow, not overkill).

I'll break it into **4 clean parts**, the way you should speak.

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## **1 MODELS DISCUSSED (WHY EACH ONE EXISTS)**

### **Linear Regression**

#### **Why used:**

Linear Regression is used as a baseline model to understand linear relationships between environmental variables such as temperature, humidity, and gas concentration levels.

#### **Why examiners like it:**

- Simple
- Interpretable
- Easy to justify

#### **Defense line:**

It provides a reference point to evaluate the performance of more complex models.

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### **Decision Tree Regression**

#### **Why used:**

Decision Trees capture non-linear relationships and generate rule-based predictions, which are suitable for environmental data with threshold-like behavior.

**Defense line:**

They are easy to interpret and align well with rule-based safety systems.

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## **Random Forest Regression**

**Why used:**

Random Forest reduces overfitting by averaging multiple decision trees trained on different subsets of data.

**Defense line:**

It performs well with noisy sensor data and improves robustness in real-world environments.

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## **Gradient Boosting Regression**

**Why used:**

Gradient Boosting sequentially improves prediction accuracy by correcting previous errors, making it effective for complex pollutant interactions.

**Defense line:**

It provides higher predictive accuracy while remaining computationally manageable.

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## **Isolation Forest (Anomaly Detection)**

**Why used:**

Isolation Forest efficiently detects rare abnormal events in unlabeled datasets, such as gas leaks or sudden pollution spikes.

**Defense line:**

It is lightweight and suitable for real-time safety monitoring.

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## 2 ML & PYTHON LIBRARIES USED (DEFENSE-SAFE LIST)

### Core Python Libraries

**NumPy** – numerical operations and array handling

**Pandas** – data loading, cleaning, and time-series handling

**Matplotlib / Seaborn** – data visualization and EDA

*(If they push back: Seaborn is optional; Matplotlib alone is fine.)*

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### Machine Learning Libraries

**Scikit-learn** – implementation of Linear Regression, Decision Trees, Random Forest, Gradient Boosting, and Isolation Forest

#### Why scikit-learn?

It is well-tested, efficient, and widely used in academic and industrial research.

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### Optional (if asked about deployment)

**Joblib / Pickle** – model serialization

**Flask / FastAPI** – serving predictions (optional, not mandatory)

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## 3 DATASETS (THIS IS A CRITICAL QUESTION)

### Primary Dataset

The primary dataset is **self-collected sensor data** from the deployed IoT system.

#### Features include:

- Carbon monoxide (MQ-7)
- LPG / methane (MQ-5)
- Hydrogen (MQ-8)
- Smoke (MQ-2)
- PM2.5 / PM10
- Temperature

- Humidity
- Timestamp

**Defense line (VERY IMPORTANT):**

Using self-collected data ensures that the models are trained on the same sensor characteristics and environmental conditions as the deployed system.

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**Supplementary / Pre-training Datasets (Optional)**

If they ask “*What if your dataset is small?*”:

Public datasets such as UCI Air Quality Dataset or OpenAQ data can be used for exploratory analysis and model validation, but final training is based on system-specific data.

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**4 TRAINING PROCEDURE (STEP-BY-STEP, EXAMINER-FRIENDLY)**

**Step 1: Data Collection**

Sensor data is collected continuously over a defined period and stored in the cloud database.

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**Step 2: Data Preprocessing**

- Removal of outliers
  - Calibration correction
  - Handling missing values through interpolation
  - Normalization of features
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**Step 3: Exploratory Data Analysis**

- Trend analysis
  - Correlation analysis
  - Identification of pollution spikes
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**Step 4: Dataset Splitting**

Data is split into training and testing sets, typically using an **80:20** ratio.

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### **Step 5: Model Training**

Each model is trained using historical sensor data to predict pollutant levels or detect anomalies.

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### **Step 6: Model Evaluation**

- RMSE and MAE for regression
  - Accuracy and confusion matrix for anomaly detection
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### **Step 7: Deployment**

Trained models are integrated into the backend to provide predictions and trigger alerts.

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### EXAMINER TRAP QUESTIONS (WITH SAFE ANSWERS)

#### **? Why not train directly on the ESP32?**

The ESP32 is resource-constrained; training is done in the cloud or PC environment, while inference and threshold logic are lightweight.

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#### **? How often do you retrain the model?**

Periodic retraining is performed as new data becomes available to handle sensor drift and environmental changes.

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#### **? What is your biggest ML limitation?**

Limited data volume due to time constraints, which is mitigated using simple, robust models.

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## ONE-SENTENCE POWER ANSWER (MEMORIZE THIS)

The selected models balance interpretability, computational efficiency, and robustness, making them suitable for low-cost IoT-based environmental monitoring.

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Your turn again 😊

Ask **harder** — sensors, calibration, overfitting, data leakage, or deployment.

okay what other models that can be used just a mention

Good — this is a **quick-name, examiner-style question**, so the answer should be **short and confident**, not explanatory.

### **Defense-appropriate answer (just mention):**

Other models that can be used include **Support Vector Regression (SVR)**, **K-Nearest Neighbors (KNN)**, **XGBoost**, **LightGBM**, **Extra Trees Regression**, **ARIMA** and **SARIMA** for time-series forecasting, **LSTM neural networks**, **Autoencoders** for anomaly detection, and **Gaussian Process Regression**.

### **If they add: “Why didn’t you use them?”**

Due to computational cost, data size limitations, and the need for interpretability, simpler and more efficient models were preferred.

That’s it — clean, sharp, examiner-safe.

### **Research Questions (RQs)**

#### **RQ1 – Sensor Accuracy**

How can low-cost IoT sensors reliably monitor household air quality parameters in real-time?

#### **RQ2 – Data Analysis & Prediction**

Can machine learning models accurately predict pollution trends and detect anomalies from short-term sensor data?

#### **RQ3 – Safety & Alerts**

How effectively can the system provide timely alerts to reduce health and safety risks from air pollution or gas leaks?

## **RQ4 – Usability & Scalability**

Is the proposed IoT-based system practical, user-friendly, and scalable for localized environments like homes and small businesses?

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## **Hypotheses (H)**

### **H1 – Sensor Performance**

Low-cost IoT sensors can accurately detect variations in household air quality parameters (CO, LPG, PM2.5, temperature, humidity) in real-time.

### **H2 – Machine Learning Prediction**

Machine learning models such as Random Forest, Decision Trees, and Gradient Boosting can predict air pollution trends and detect anomalies with acceptable accuracy using short-term sensor data.

### **H3 – Safety & Alerts Effectiveness**

The system can generate timely alerts that reduce potential health and safety risks from gas leaks or poor air quality in localized environments.

### **H4 – Usability & Scalability**

The IoT-based air quality monitoring system is practical, user-friendly, and scalable for household and small business deployment.