



Carbon monoxide concentrations in urban and extra-urban areas

FLIGHT RESOURCE CENTER



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● **SHORT DESCRIPTION**

This project engages students to understand how drones can be an important key for data collection. Students explore the intersection of human infrastructure and pristine natural environments. Monitoring a Heating Ventilation and Air Conditioning (HVAC) system or a Heating Plant (e.g., a biomass boiler or gas furnace) in a natural area allows students to measure how "point-source" combustion plumes interact with clean, high-oxygen mountain or forest air.

In a protected natural area, the air should theoretically be devoid of CO. While the EU has successfully slashed industrial CO emissions by **90%** (EEA 2025), a single malfunctioning or inefficient heating plant (biomass, gas, or oil) can create a concentrated "toxic pocket."

Students learn that CO is the primary marker of incomplete combustion.

Students set up an air quality logger as a payload, attach it to the drone, plan a simple flight path and operate a drone. They document the process with pictures and short videos that later will become learning materials. Safety considerations should be frequently mentioned. This project will allow students to question themselves about how the world will be in 10/15 years and concerns about current environmental care of the world in general.

● **TARGET**

15
16
17
18
Over 18

● **SUBJECT AREA**

Agriculture
Disaster Response
Constructions
Water Management
Environmental Protection
Other

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● **TYPE**

Lesson Plan
Project

Activity

● **DRONE USED**

Custom Drone

Commercial drone (DJI)

● **DURATION**

- ☐ 1 x 45-minute class
- ☐ 1 x 60-minute class
- ☐ 1 x 90-minute block
- ☐ 2 x 45-minute classes
- ☐ 2 x 60-minute classes
- ☐ Double session (2 × 60 minutes) optional project-based homework.

● **LEARNING OBJECTIVES**

O1: Identify and compare the specific combustion fingerprint of a heating system versus the pristine baseline of a natural area. Influencing air quality.

O2: Plan and execute a safe and responsible drone flight mission to detect carbon monoxide over a simulated or real-world area of interest, aligned to established pre-flight safety protocols.

O3: Analyze the collected sensor data by cleaning the logged .csv file and mapping the drone's flight path and corresponding air quality and CO readings.

O4: Interpret data to draw conclusions about air quality patterns and discuss the role of drone technology in monitoring environmental parameters.

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● **KEY COMPETENCES DEVELOPED**

1. Communication and Languages

- ☐ Literacy competence (understanding and producing written/oral texts)
- ☐ Communication in professional contexts
- ☐ Multilingual competence

2. Mathematical, Scientific, Technical and Professional Skills

- ☐ Mathematical competence
- ☐ Scientific, technological and engineering competence (STEM)
- ☐ Numeracy applied to work tasks
- ☐ Interpretation of technical information (manuals, diagrams, standards)
- ☐ Professional/technical skills
- ☐ Execution of practical tasks

3. Digital Competences

- ☐ Digital competence (general digital literacy)
- ☐ Use of digital tools in workplace settings

4. Personal, Social and Professional Competences

- ☐ Personal, social and learning-to-learn competence
- ☐ Teamwork and collaboration
- ☐ Autonomy and responsibility
- ☐ Work ethics and professional behaviour
- ☐ Adaptability and flexibility

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- ☐ Cooperation with supervisors and colleagues

5. Safety, Quality and Sustainability

- ☐ Application of health and safety standards (OHS/SST)
- ☐ Quality procedures and workplace norms
- ☐ Environmental and sustainability awareness

6. Citizenship and Cultural Competence

- ☐ Citizenship competence
- ☐ Cultural awareness and expression competence

7. Creativity, Problem-Solving and Entrepreneurship

- ☐ Problem-solving and critical thinking
- ☐ Entrepreneurship competence
- ☐ Initiative and creativity
- ☐ Decision-making in real work situations

8. Work-Based Learning and Workplace Integration

- ☐ Integration into workplace routines
- ☐ Following professional instructions and procedures
- ☐ Use of tools, equipment and technology

This checklist merges the EU Key Competences for Lifelong Learning with the core competences expected in European Vocational Education and Training (VET).

● **Prior Knowledge / Prerequisites**

Students should have a foundational understanding of drone piloting safety protocols and basic electronics, including experience with connecting components on a breadboard. While advanced programming knowledge is not required for this project, a

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working familiarity with the Arduino IDE is highly recommended. Specifically, students should be comfortable setting up the IDE for the ESP8266 board and uploading code to a microcontroller, as detailed in the FLIGHT KIT handbook materials.

A foundational awareness of general environmental issues will be beneficial for contextualizing the project's purpose and engaging in discussions about the real-world implications of their findings.

● **Lesson/Project Outline**

Phase 1 – Introduction (Engage & Contextualize)

The session begins by examining the critical stakes of air quality, emphasizing a startling physiological fact: humans inhale roughly 14kg of air daily—far more than the food or water we consume. Among the various pollutants, Carbon Monoxide (CO) stands out as one of the most dangerous threats to both human health and the environment.

As a byproduct of incomplete combustion from transport, heavy machinery, and heating systems, CO is often called the "silent killer" because it is colorless, odorless, and highly toxic. In natural areas, where air is expected to be pristine, the presence of CO from a local heating plant or HVAC system is a "smoking gun" of human environmental impact. This leads to our central inquiry: *"How can we accurately detect, measure, and map these invisible gases to protect public health and monitor environmental footprints in sensitive ecosystems?"*

The solution lies in the MQ7 Gas Sensor, a specialized electrochemical component designed to detect CO concentrations in parts per million (ppm). We will introduce the integration of this sensor into a custom drone payload, creating a high-tech, mobile laboratory.

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“Gola della Rossa” Natural park panoramic view. Source: <https://www.parcogolarossa.it/>

Guiding Questions:

1. What types of air pollutants might be found near a geothermal environment and what are their sources?
2. Why is using a drone more effective for this task than taking measurements from the ground?
3. What challenges might we face when flying a drone and collecting data in a real-world environment?

Phase 2 – Exploration (Investigate & Compare)

In this phase, students move from a general discussion of air quality to a focused exploration of how drones and sensors can be used to collect environmental data safely and effectively in hard to reach natural areas. The goal is to understand the possibilities and limitations of using a custom drone with a custom air quality sensing system.

Students are first introduced to the components of the air quality logger. The trainer explains the role of each element: the BME680 sensor measures temperature, humidity, pressure and VOCs, the MQ-7 sensor measures carbon monoxide levels, the ESP8266 microcontroller manages data collection, and the SD card stores the data. The following handbooks are good for a better understanding:

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- [2.2.1. Getting Started with NodeMCU](#)
- [2.2.2. Environmental Sensing Modules](#)
- [2.2.3 Data Acquisition, Logging and Field Operations](#)

The trainer then introduces the MayFly custom drone and its application for environmental protection.

Attention is then given to the challenges of attaching a custom payload to a drone. The importance of keeping all safety systems enabled is strongly emphasized, reinforcing responsible and professional drone operation.

Using Google Maps, students should choose an area to then be able to plan a flight in that zone.



Panoramic view of the natural park with a local thermal spa facility. Source: GoogleEarth

In the selected natural environment, students plan a strategic flight route to detect carbon monoxide concentration nearby the thermal spa heating system. Using a satellite view of the facility, groups identify specific "hotspots" where CO concentrations are expected to be highest.

In this case, the primary study zone is the atmospheric layer directly above and downwind of the spa's heating vents along the riverbank. This is a critical area because the river canyon's effect and the water's movement can create a microclimate that either traps warm, buoyant CO near the tree canopy or channels it downstream into lower-lying natural pockets.

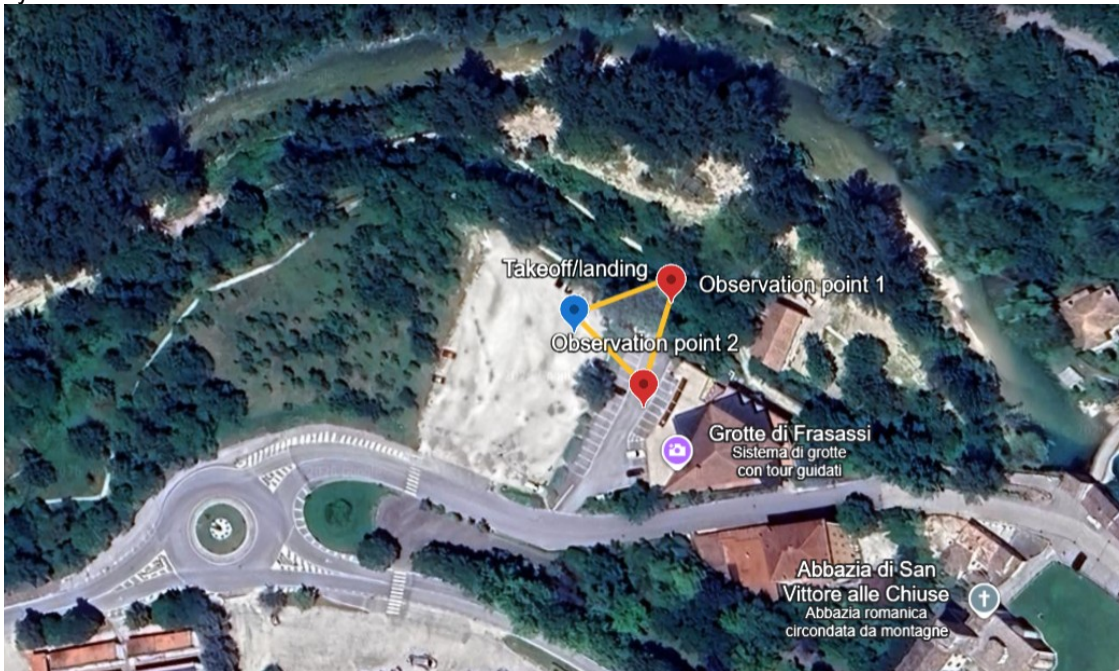
Before approaching the facility, students establish a Control Point located upwind from the spa. This allows the drone to measure the background air quality of the natural area before it is influenced by the facility's combustion activities. By establishing this "Clean Air Baseline," students can accurately calculate the exact Parts Per Million (ppm) increase contributed by the spa's heating

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system.



Groups discuss flight height, direction of movement, and points where slower flight may be needed to improve data quality and reduce payload swing. An important thing to tell students before they start this task is to keep respect and don't fly over people/buildings without their permission

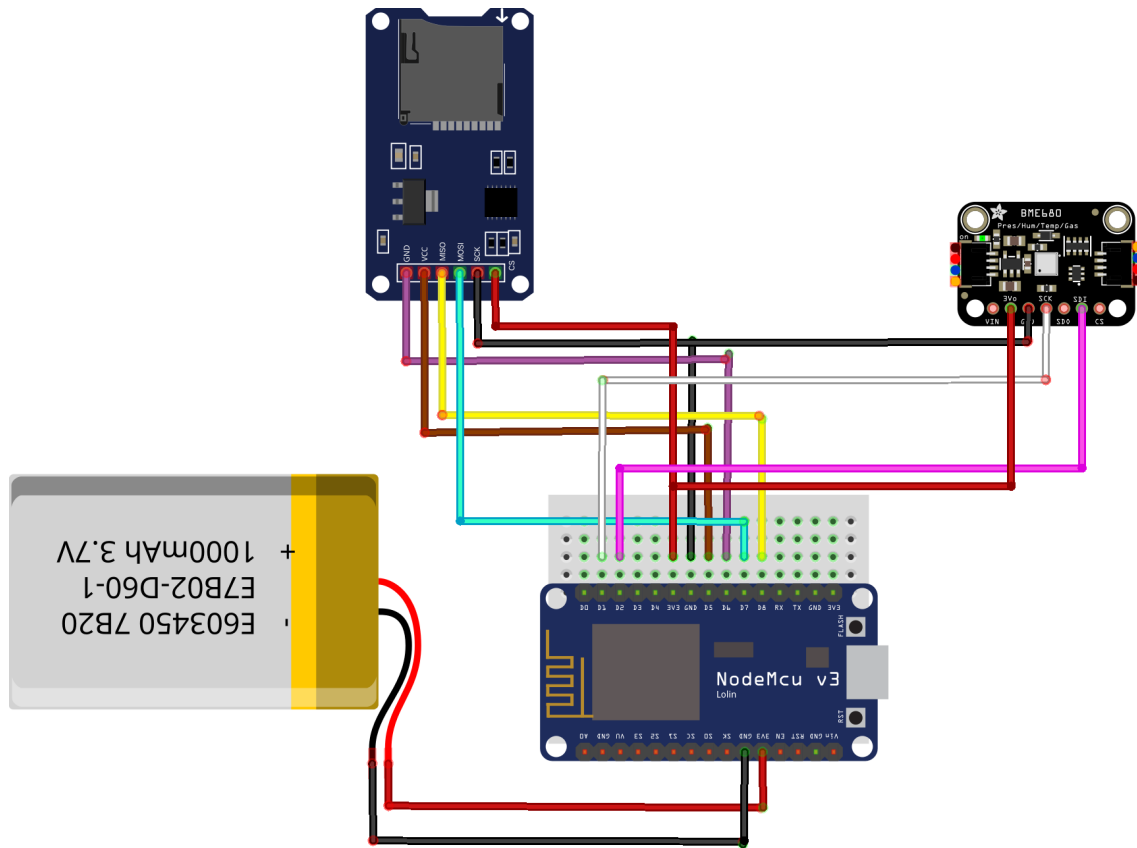
Phase 3 – Application (Hands-On Practice)

The session begins with a brief introduction to the technical handbooks, which guide students through the setup of the ESP8266, basic sensor testing, and SD card preparation. Using the provided circuit diagram and source code, the trainer explains how ESP8266 connects to the MQ-7 sensor, and SD card, focusing on the purpose of each component. Students upload the code and verify that data is being recorded correctly before integrating the system with the drone.

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fritzing

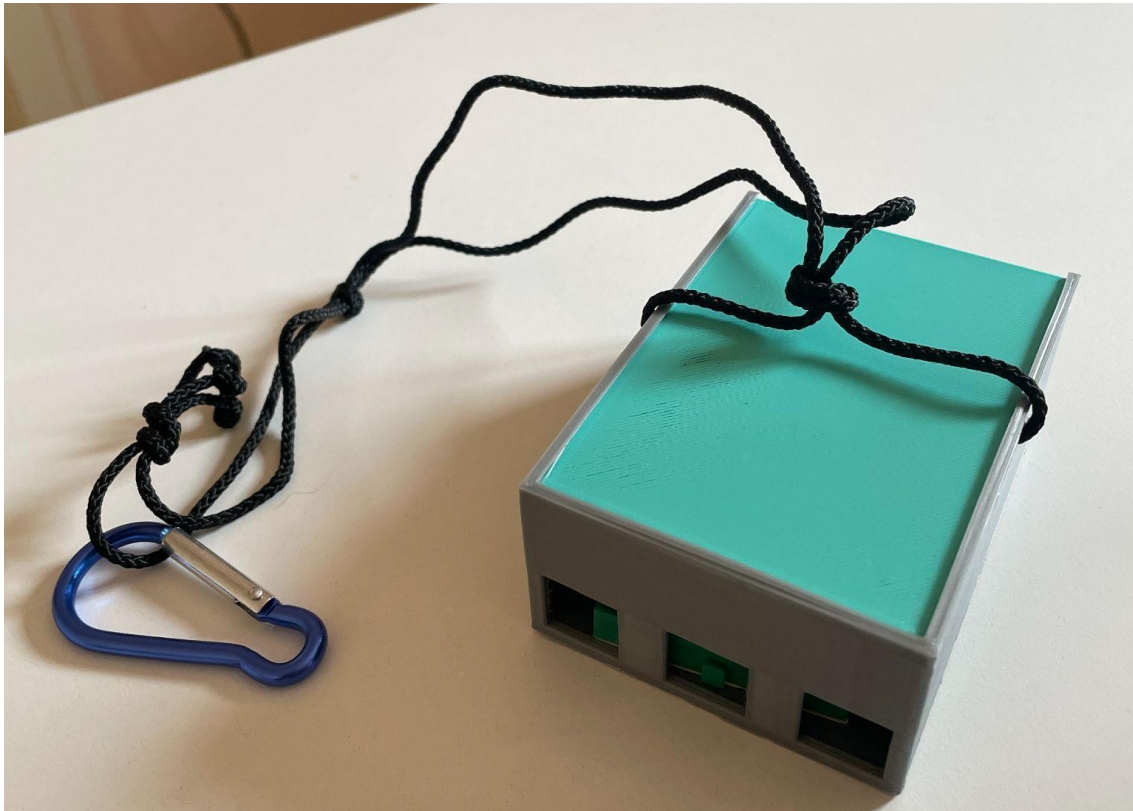
The circuit diagram provided is for illustrative purposes. Due to market availability and different manufacturers, the physical components in your kit may vary slightly in color, shape, or pin arrangement compared to the images. Do not rely solely on visual matching; always read the silkscreen labels printed on your specific modules to ensure correct wiring.

Students then assemble the suspended payload system to the custom drone. The payload is secure under the drone with a velcro strip. Another option is to use a plastic threat with a clip to attach the payload to the custom drone. A pre-flight check is carried out to ensure that the payload suspension is secured, and active data logging.

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Custom drone payload

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Custom drone with payload

The flight is conducted slowly and smoothly along the planned route, using gentle movements to reduce payload swing.

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Custom drone payload hovering the HVAC system to detect CO emission

After the flight, the payload is detached, the drone is landed safely, and the SD card is removed. Students transfer the recorded data to a computer.

The following table illustrates the monitoring results recorded during a defined moment (December 22, 2026). The data, recorded by the BME680 and MQ7 gas sensors, includes temperature, humidity, gas, altitude, and CO levels, and is provided to support the creation of a worksheet for trainers to use with students.

Temp (°C)	Humidity (%)	Pressure(hPa)	Gas Resistance (kOhms)	Altitude (m)	CO Level (ppm/Analog)
13.48	80.35	991.61	32.9	181.66	533
13.36	79.56	991.61	37.63	181.66	601
13.24	79.31	991.62	43.98	181.58	640
13.2	79.6	991.64	50.38	181.41	667
13.2	79.87	991.65	56.58	181.49	676
13.24	80.06				

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		991.64	63.05	181.49	686
13.3	80.14	991.65	69.14	181.41	708
13.34	80.12	991.65	74.1	181.41	715
13.39	79.75	991.65	79.21	181.49	721
13.44	79.23	991.64	85.35	181.58	721

These results reinforced the mission's primary objective (O4) by demonstrating the efficacy of drone-based environmental monitoring. The flight plan, generally conducted between expected hotspots, allowed for the collection of CO concentration levels in proximity to emissions sources such as Heat, Ventilation and Air-Conditioning (HVAC) systems in urban areas. This mission effectively showcased how drone technology, equipped with the BME680 and MQ7 sensors, can be utilized as a tool for students to analyze air quality patterns, interpret environmental data, and discuss the role of remote sensing in detecting key pollutants (VOCs and CO concentration levels in urban and natural areas

Phase 4 – Reflection & Consolidation (Present & Connect)

Group Presentations

Each group prepares a short presentation that reviews the main stages of the project. Students explain the flight route they planned and present the data collected in each observation point. They also describe what patterns they observed in the CO emission data and discuss possible reasons for differences between locations. The focus remains on interpreting environmental data rather than drawing definitive conclusions.

Class Discussion:

After the presentations, the trainer leads a discussion. Students compare results from different groups and identify similarities and differences in pollution patterns across the study area. The discussion encourages critical thinking about data interpretation and the limits of drone-based measurements. Key discussion points include:

- How mapped sensor data helps identify patterns in CO emission nerry HVAC systems.
- What limitations exist when using short-duration drone measurements.
- How variables such as current wind speed/direction influence the concentration and movement of pollutants.
- Why safety and responsible drone operation are essential in every environment.
- How this type of data could support environmental awareness or decision-making.

Reflection Activity:

To conclude the project, students complete a short individual

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reflection, supported by guiding questions or written prompts. They reflect on both technical and environmental learning, including:

- What they learned about collecting air quality data using drones.
- How piloting with a suspended payload influenced decision-making.
- The role of planning, safety, and teamwork in successful fieldwork.
- How air pollution can affect urban life and human health.

Quiz

- Carbon Monoxide (CO) is primarily a byproduct of "incomplete combustion." In which of these scenarios is CO most likely to reach dangerous concentrations?**
 - A well-ventilated forest during a light breeze.
 - An enclosed underground urban parking garage with poor ventilation.
 - A solar power plant during peak sunlight.
 - An open maritime coastline.
- Carbon Monoxide is often called the "_____(Silent killer)" because humans cannot smell, see, or taste it, even when it is at dangerous levels.**
 - Why does CO pose a greater environmental health risk in urban areas compared to extra urban ones?
 - Because there is more oxygen in cities.
 - Because tall buildings trap the gas and prevent vertical dispersion.
 - Because CO is attracted to concrete surfaces.
 - Because urban areas have higher humidity which produces more CO.
- The MQ7 sensor uses a Tin Dioxide sensitive layer. When it encounters Carbon Monoxide, what happens to the electrical resistance of the sensor?**
 - The resistance increases.
 - The resistance decreases, leading to a higher voltage output.
 - The resistance remains constant regardless of gas levels.
 - The sensor stops conducting electricity entirely.
- Match the component to its specific job in the mission:**

Component	Main Function
A) MQ7 Sensor	1. Provides the "Where" (Latitude/Longitude)
B) MicroSD Module	2. The "Digital Nose" (Detects CO)

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C) GPS Module	3. The "Brain" (Processes the signals)
D) NodeMCU	4. The "Memory" (Stores the .csv data)

6. Why is the "heating-up" phase of the MQ-7 sensor critical before starting any measurements?

- a) To ensure the drone's rotors spin at the correct frequency.
- b) To allow the Tin Dioxide layer to reach the operating temperature necessary to react with CO molecules.
- c) To save power on the SD card module.
- d) To calibrate the drone's compass against the heating plant's magnetic field.

7. True or False: Carbon Monoxide (CO) disperses uniformly at all altitudes regardless of the heating plant's chimney height.

- a) True b) False

8. What is the main risk when flying a drone near an HVAC system or an industrial vent?

- a) The drone might record too much data.
- b) Turbulence from the vents can destabilize the drone or alter gas concentration readings.
- c) The drone's battery will charge faster due to the heat.
- d) The MQ-7 sensor will automatically turn off the drone's motors.

9. Why is it recommended to fly the drone slowly when approaching an HVAC exhaust point?

- a) To save battery for the return flight.
- b) To allow the MQ-7 sensor enough "residence time" to stabilize and detect the CO plume accurately.
- c) To keep the drone in sight of the pilot at all times.
- d) Because drones are legally required to fly slow near buildings.

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10. If the MQ-7 records a sharp CO spike while the drone is in the "Clean Air Baseline" zone, what does this suggest?

- a) The sensor is malfunctioning due to high oxygen levels.
- b) There might be an unmapped source of combustion or a sudden change in wind direction carrying the plume.
- c) The drone is flying too slowly.
- d) The SD card is full.

Answer

- 1. **b (B)**
- 2. **Silent killer**
- 3. **b (B)**
- 4. **A-2, B-4, C-1, D-3**
- 5. **b (B)**
- 6. **b**
- 7. **b**
- 8. **b**
- 9. **b**
- 10. **b**

● **Assessment Criteria**

Student learning is assessed using the following criteria:

- The student demonstrates an understanding that the MQ7 Gas sensor register carbon monoxide concentration levels emitted by HVAC.
- The student contributes to flight planning and explains decisions related to route, height, and safety.
- The student participates effectively in group work, respecting roles and contributing to shared tasks.
- The student presents information clearly, using visual data to support explanations.

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- The student reflects on both the potential and the limitations of drone-based environmental monitoring and recognizes the importance of safe and responsible technology use.

● Teaching Materials

Resource	Link
1. Custom drone MayFly	https://docs.google.com/document/d/1fFlacOnKI3LNpETiJVghhQkoenCvt5ct/edit?usp=drive_link&oid=110204741178376447896&rtpof=true&sd=true
2.2.1. Getting Started with NodeMCU	https://docs.google.com/document/d/1kQglg533Jtssm3LG2PeQFb5h1b1OKwSLQl-dx8GvcHM/edit?usp=drive_link
2.2.2. Environmental Sensing Modules	https://docs.google.com/document/d/1TaEKu4fmXjR0nPVU_rB5BKxXWu_l-oj9cHaotPzbTBc/edit?usp=drive_link
2.2.3 Data Acquisition, Logging and Field Operations	https://docs.google.com/document/d/19S4BqSk_Rdi75qzwWkpkeVnbt9otIEB-O9kfYv9Ww/edit?usp=drive_link

2- FLIGHT Kit (custom drone components) used:

- ☐ BME680 – Temperature, Humidity, Pressure, VOCs
- ☐ Laser PM2.5 Sensor – Particulate Matter
- ☐ MQ7 Gas Sensor – CO Detection
- ☐ GUVVA-S12SD – UV Intensity

● External Resources

Resource	Link
Emissions of air pollutants from transport in Europe (Published 21 Oct 2025)	https://www.eea.europa.eu/en/analysis/indicators/emissions-of-air-pollutants-from

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EU air quality standards, European Commission	https://environment.ec.europa.eu/topics/air/air-quality/eu-air-quality-standards_en
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