Selecting low-cost sensors for air quality monitoring

Sustainable Communities and Waste
National Environmental Science Program

Guidance for households

About this fact sheet

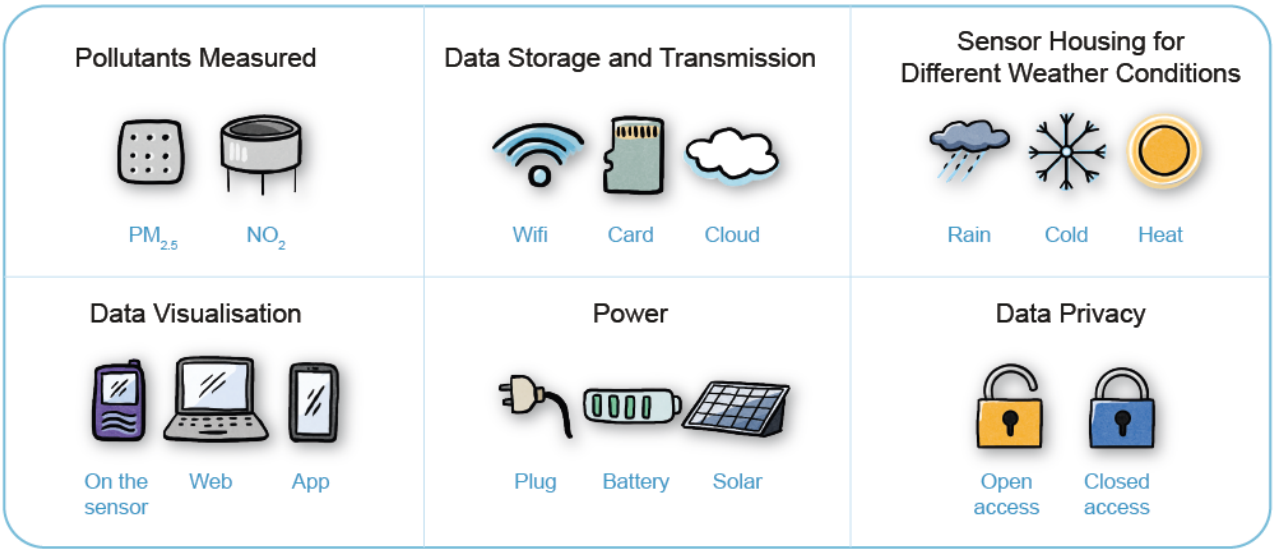
The rapid evolution of low-cost sensors means more and more Australian consumers now have an affordable way to monitor air pollution. But with dozens of models available, and wide-ranging prices and features, it can be time-consuming to select the right device.

This fact sheet provides guidance for households seeking to buy low-cost sensor devices to monitor indoor or outdoor air. It covers devices that measure particulate matter (PM), polluting gases, and volatile organic compounds (VOCs), and complements our online low-cost sensor selection tool: monitors.cleanairstars.com

This guidance does not cover carbon dioxide (CO_2) monitors, such as the Aranet4, commonly used to check whether indoor ventilation is adequate.

Choose a product to suit your needs

Members of the public concerned about the air they breathe can use low-cost sensors to monitor personal exposure to indoor pollutants from sources such as gas cooktops or wood-burning stoves. They can also monitor outdoor pollution emitted by vehicles, factories or bushfires. Understanding pollution levels can help you and your family address potential health risks by taking action to reduce exposure.



Key things to consider

The sections below cover some key features to consider before you buy a low-cost sensor device.

Indoor, outdoor or portable?

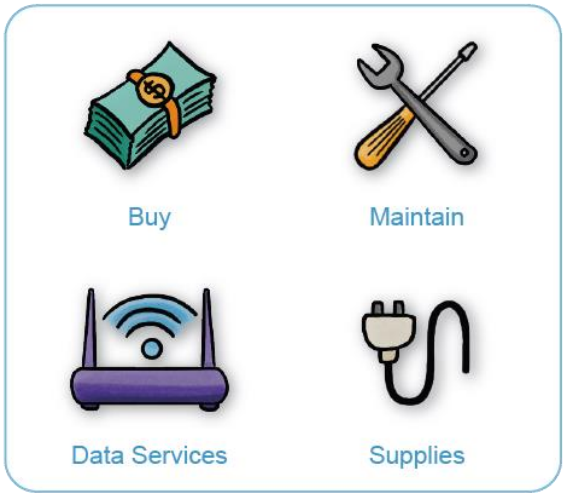
If you're only concerned about air quality inside your home, consider buying one of the many affordable models specifically geared to monitor indoor air.

If understanding more about air pollution outside your home is your goal, look for one of the more weather-proof monitors designed for outdoor use. Be aware that if a monitor is specified only for outdoor use, it's not a good idea to use it for indoor air monitoring too. Instead, look for one of the models labelled for **both** indoor and outdoor use.

A growing number of portable monitors also makes it possible to monitor air in a variety of locations, such as inside and outside your home during bushfire season, or along roads children use to walk to school.

Costs

Different models of air quality sensor devices vary greatly in price. This guidance and our online tool cover devices less than AUD$10,000. Many households will likely opt for the growing number of models under $500. Cost generally increases with the number of pollutants a device measures, and accuracy and sensitivity of its sensors.



Most manufacturers offer devices for a one-off purchase price, but some offer units on a subscription basis. Before you buy, consider the total cost of ownership. This includes not only the purchase or subscription price for the unit, but any additional and long-term operating costs as well, such as:

- installation costs
- subscriber services for viewing the air quality information
- technical support
- maintenance, including repairs.

Select a device that measures pollutants you're concerned about

Low-cost sensors only detect the specific pollutants they're designed to monitor. Be sure your chosen device measures the pollutants you're concerned about. The types and number or pollutants a device measures affect its cost.

These are the main classes of target pollutants measured by LCS devices:

1. **Particulate matter** are particles from burning fuels. These include PM_1 (extremely fine particles with a diameter 1 micron or less, or 100 times smaller than a millimetre), $PM_{2.5}$ (fine particles of 2.5 microns or less), and PM_{10} (particles of 10 microns or less). These small particles pose a health hazard because they can travel deep into lungs, some even into your bloodstream. Most PM sensors measure $PM_{2.5}$ with reasonable accuracy, but typically do a poor job of measuring PM_{10}. The lifetime of PM sensors varies, but generally ranges from 1 to 4 years.
2. **Gases**: Nitrogen dioxide (NO_2) or ozone (O_3) are polluting gases released by burning fuels. Low-cost sensors generally measure gases with less accuracy than PM sensors. It can be quite expensive to buy a device that measures these gases accurately. Gas sensor lifetimes range from 6 months to 2 years.
3. **Volatile organic compounds (VOCs):** This is a broad class of polluting particles, many of them produced by humans. Some VOCs have short- or long-term adverse health effects. Most low-cost sensors do a poor job of measuring VOC pollutants accurately and can be very costly.

Things that affect the quality of measurements

Accuracy: Depending on your goals, the accuracy of your device's sensors may be important. Accuracy varies greatly between the different models of low-cost sensor devices, and even within a model for the different pollutants it detects. Check the device's accuracy for each pollutant you wish to measure.

Accuracy, the ability to hit a target, refers to how well a sensor's pollution measurements agree with those of a highly accurate reference instrument. Accuracy is often expressed as an R^2 value, a statistical term. The closer the R^2 value to 1, the stronger the agreement and the greater the accuracy, with 1 being a perfect agreement.

Reliable manufacturer information about accuracy can be hard to find. Here independent evaluations of sensor models may be of use. If they're available, these independent evaluations can provide insight into sensors' accuracy and other aspects of the device's performance (see 'Resources'.)

Precision is the ability to hit a target time after time. It refers to how well a sensor reproduces a measurement under identical conditions. High precision may be important if you wish to measure small differences in pollution.

Sampling rate is the rate at which a sensor can take measurements. A high sampling rate may be important if you're trying to understand how pollution levels change rapidly in space or time.

Calibration: Calibration is a way to check and adjust sensor settings, to ensure its measurements compare well with a known and certified standard. It's a good idea to check whether a device's sensors have been calibrated by the manufacturer at the factory before you purchase it.

Consider how the device manages information

Some models, including many indoor monitors, have on-device displays, where you can read the air quality information. Some use coloured LED lights to alert you to changes in air quality.

Other models transmit air quality information to a server, for viewing on an app or website. These models transmit data in a variety of ways: Wi-Fi, Bluetooth, satellite, 4G and low-power wide-area network (LoRaWAN). Be sure the model you choose transmits data in a way that suits your set-up at home. For example, if it transmits using Wi-Fi, and you plan to install the sensor outside, you'll need to make sure your Wi-Fi signal is strong enough.

Some basic models simply store information on the device, for example, on an SD card, from where you manually retrieve it.

Be sure to consider any extra costs related to the handling your device's information, such as mobile subscription services or the subscriber fees some manufacturers charge to view information online.

Consider ease of use

For most households, it's important to buy a low-cost sensor device that's intuitive and easy to use. Before you buy, check whether any special expertise is needed to operate the device. Find out if you'll need to purchase tools, computers or software. Check if it's easy to tell whether the device continues to operate properly, without interruption. Device size and weight may also be important, especially if you're looking for a portable model.

Installation: Check whether the device is easy to install. Will installation work in your planned location, without becoming difficult or expensive? Models that are less complex and technical in terms of installation may be the best bet.

Power options: Choose a device that matches your power needs. Devices that plug in are often the best option if you only want to monitor in a single spot. Many models also have batteries or USB power supplies, useful if you are monitoring in different places. Solar power, an option for some models, can be costly.

Operation and maintenance: Make sure the device is tough enough to tolerate expected wear and tear, such as being dropped if it's a portable unit. If it's outdoors, ensure it comes with an enclosure that's durable enough to withstand expected extremes of heat, cold or moisture and dust.

All low-cost sensors have limited lifespans and can become less accurate over time. Check the manufacturer information to see how long the sensors are likely to operate before you need to replace them or purchase a new device. Check too whether special expertise is needed to perform any necessary maintenance.

It may be wise to pick a model that has a warranty and a good-quality manual. It's also a good idea to confirm whether the sellers provide responsive customer service, such as a team dedicated to ongoing support.

Useful resources

Independent LCS evaluations

- Airlab
- AQ-SPEC Air Quality Sensor Performance Evaluation Center of California's South Coast Air Quality Management District (AQMD). Due to geo-blocking, you may need a VPN to access South Coast AQMD web pages.
- Evaluation of emerging sensor performance (US EPA)

Guidance on how to plan and run LCS projects

- Community in action: A comprehensive guidebook on low-cost sensor (South Coast AQMD)
- The enhanced air sensor guidebook (US EPA)
- Forum Sensor.Community

Guidance on air filters to improve indoor air quality

- Clean Air Stars