OPENAIR

Operational Network of Air quality Impact Resources

# Sensing device performance evaluation methodology

SR202

December 2023

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# Introduction

The abundance of commercially available, low-cost air quality sensing devices can make selecting an appropriate product for your sensing project a complex decision. It can also be difficult to evaluate the performance of these devices. Unlike regulatory grade equipment used for state government-run air quality monitoring networks, low-cost sensing devices are not made to certified or legal standards (United States Environmental Portection Agency, 2022).

This means it is important that you develop a methodology to evaluate the performance of the low-cost sensing devices you need to use in your project. This OPENAIR resource will guide you in developing appropriate performance requirements for your project's sensing devices, interpreting data sheets and reports, and taking the necessary steps to evaluate a particular sensing device to ensure your project goals are achieved.

The evaluation methodology presented in this resource is informed by the recommendations of the United States Environmental Protection Agency (U.S. EPA), and by the OPENAIR supplementary resource *A framework for categorising air quality sensing devices*.

Before you start to think about evaluating the performance of various types of sensing devices, use the OPENAIR Best Practice Guide chapter *Sensing device procurement* to better understand the general process of selecting and procuring smart low-cost air quality sensing devices.

# Who is this resource for?

This resource is for local government staff who are tasked with leading the project planning and procurement activities for an air quality sensing project, and who may be seeking guidance on selecting the best devices to meet their project's stated goals.

While this resource is designed to be useful to staff who do not have a technical background in air quality sensing devices, electronics, or statistics, it does contain some fairly complex technical terms and concepts. These will be explained where appropriate.

# How to use this resource

The sensing device evaluation process described in this resource should be followed only after you have completed a project plan and 'data use action statement'. For practical guidance on developing these, refer to the OPENAIR *Identify template*.

The evaluation methodology presented in this resource can be used to inform the design of your smart air quality monitoring project. It can also help you to interpret the data produced by smart low-cost air quality sensing devices.

This methodology can be used to evaluate the performance of a sensing device, by helping you to understand:

- how the internal components of a sensing device affect performance

- what the specifications on a data sheet and third-party test report actually indicate
- what type of evaluation process is appropriate for a device, based on available resources.

# Evaluating sensing device performance

An initial evaluation of sensing device performance can be carried out based on readily available information and/or documentation provided by the device manufacturer or vendor.

The information that is most useful in evaluating the performance of sensing devices includes:

- documentation about your project’s technical requirements
- the types of sensors found within sensing devices
- the limitations of various types of sensors
- data sheets and statistics
- any existing performance evaluation reports.

## Technical requirements

Any evaluation of sensing devices must always be done with a clear understanding of what your project hopes to achieve. A sensing device appropriate for one purpose (e.g. air pollution hotspot identification) may not be suitable for another (e.g. air pollution compliance monitoring).

Using the OPENAIR supplementary resource *Technical requirements template* (as well as *A guide to developing technical requirements* and *A framework for categorising air quality sensing devices*), you should already have a good sense of the technical requirements for your project. These requirements will be informed by your target pollutants, and by your project’s acceptable quality metrics (e.g. accuracy and precision of data). Table 1 provides an example of technical requirements for a typical sensing project.

*Table 1. Example of technical requirements for a sensing project*

| **Parameter** | **Required specification** |
|---|---|
| Project scenario | Investigating whether the residential area near a highway is exposed to high levels of $NO_2$. The outcome of this report is to justify the purchase of more accurate and expensive sensing equipment, should the hotspot be confirmed. |
| Tier | Tier 2 – Hotspot identification |
| Pollutant | $NO_2$ |

| Parameter | Required specification |
|---|---|
| Target concentration | Higher concentrations than normal are expected near the highway, however the regulation NEPM standard (Office of Parliamentary Counsel, 2021) states a maximum 1-hour average of 80 ppb. This target is chosen because you would like to determine whether the maximum is exceeded or not. |
| Maximum error (precision) | The ambient hourly average is 20 ppb in your area. You want to be able to discern between ambient and high-level readings. Therefore, even with maximum error, you need to be certain that the true reading is 80 ppb or above.<br>An error of 50% allows for a good buffer zone between the ambient and maximum limit, while allowing for readings in between.<br>This means that when levels reach 160 ppb, you know the true reading is at least 80 ppb. Ambient levels generally fall between 10-30 ppb, which is at a level distinct enough to discern a hotspot event, should it arise. |
| Concentration range for which the maximum error will not be exceeded | After assessing the area for any other pollutant sources of $NO_2$ (or interfering gas sources that may influence readings), you do not believe that the concentration will reach much higher than the NSW EPA limit.<br>To ensure that you can confidently read values of 80 ppb, taking into account a measurement error of 50%, a measurement range of 100-240 ppb is selected. |

Some questions that may arise from the example used in Table 1 **will be answered in the sections to follow**, including:

- **Question 1:** Why use such a low-accuracy specification for $NO_2$?
- **Question 2:** Why focus only on the range between 100-240 ppb (instead of 0-240 ppb)?
- **Question 3:** How is it possible to know if specific sensors meet project requirements, and where can that information be found?
- **Question 4:** What about other sensor parameters, such as power, communications, and software interfaces?

**Systematically tackle the above throughout this report with the answer of each of the above points addressed at the end of each section.**

## What is in a sensing device?

An air quality sensing device is an integrated system. It consists of sensors that measures pollutants, as well as surrounding control electronics, power supply, memory storage, network connections, and mechanical enclosure. The sensors within are the limiting factor when it comes to performance; therefore, it is important to understand their limitations due to the physical mechanism in which they operate. It is the performance of the device as a whole that we are evaluating during co-location field tests.

Figure *1* shows common sensor types found in air quality devices:

- **Gas sensors**

  These are usually embedded into a circuit board as an individual electronic component. The dominating brand across devices are Alphasense gas sensors, of which there are two sensing mechanism types – electrochemical (the most common), and metal oxide semiconductor (MOS). Gas sensors are sensitive to temperature (and even more so to humidity), which affects the chemistry – and thus the longevity – of the sensor. Alphasense provides various application notes regarding the subtleties and complexities of using their electrochemical sensors at a component level. You can find more information on how environmental changes affect readings in (Alphasense, 2013a).

- **Particulate matter (PM)[1] sensors**

  All commercially available, low-cost sensors use optical-based methods to detect aerosol particles and their concentration (Giordano et al., 2021). Unlike gas sensors, PM sensors are found in module form, with their own embedded electronics (which have firmware to apply proprietary correction factors to the raw data output). One of the most popular PM modules is the Plantower PMS5003, which is found across a wide variety of devices (regardless of cost or brand name).

- **Temperature and humidity sensors**

  These sensors are usually small, integrated chips that are soldered to a circuit board and come with detailed datasheets associated with their part number. Integrated chips (like all semiconductors) undergo stringent quality assurance processes. The accuracy of their measurements are not as susceptible to other environmental parameters (unlike gas and PM sensors that are highly dependent on temperature, humidity, hygroscopic particles, interring gases etc.). Therefore, evaluation of these sensors is not necessary, as they do not deviate from the specifications present on their datasheet.

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[1] PM (particulate matter) refers to airborne solids or liquids. Its size is measured in micrometres and is indicated by the subscript. E.g. $PM_{10}$ has a diameter of 10 micrometres or less. (NSW Health, 2020)

*Figure 1. Common sensors, from left to right: Alphasense $NO_2$ Electrochemical Sensor (Alphasense, 2013c); Plantower PMS5003 Module (Core Electronics, n.d.); TMP117 Temperature Sensor (Mouser Electronics, 2018)*

## Sensor limitations

All sensor types have certain limitations, based on how they are constructed (and/or intended to function). You should be aware of the general limitations of each kind of sensor. This will help you to formulate technical requirements for your project that are reasonable, and more likely to be met. Your device performance expectations should also be closely aligned with your business plan and proposed data use case.

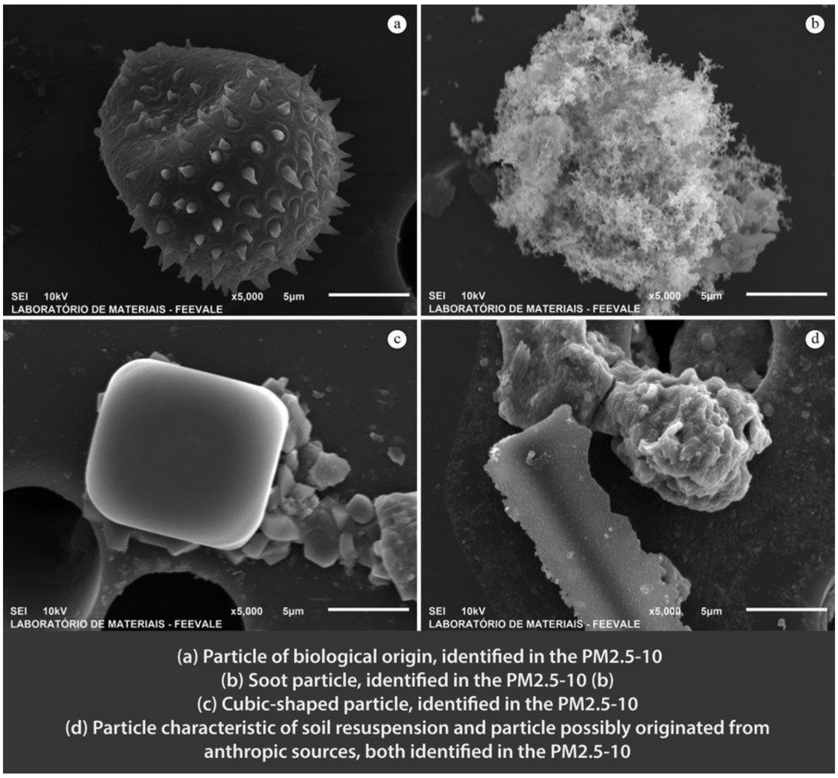
**Gas sensors** used in low-cost air quality sensing devices are typically of the electrochemical type. These sensors rely on a specific concentration of an electrolyte being present in the cell to properly detect a target gas. Potential limitations of gas sensors include:

- High ambient relative humidity (RH) will result in the cell absorbing more moisture than it can handle. RH values above 90% will cause the sensor to leak, reducing sensitivity and potentially allowing for development of corrosion of the electronics. Low ambient humidity (RH under 15%) will dry up the cell, and the electrolyte will cease to work. These factors affect readings and the longevity of gas sensors (Alphasense, 2013b).
- The biggest issue with gas sensor performance is cross-sensitivity. Not all gas sensors react solely to the gas they are designed to measure; some sensors will detect the presence of *other* gases, to varying degrees (depending on exposure concentration). For example, $NO_2$ gas sensors are cross-sensitive with $O_3$, which means if ozone is present in the atmosphere, it will be measured as $NO_2$ (Aeroqual, 2021).
- Cross-sensitivity is why co-location with a reference instrument can compare poorly when this factor is not taken into account (Crowcon Detection Instruments Ltd, 2020). The best course of action is to be aware of any interfering gases in your co-location and deployment areas, and to know to what degree your electrochemical gas sensors will be affected. You can also correct for interference by purchasing a highly selective sensor that will measure the interfering gas, and use that data to adjust the measurements of the gas your project is focused on measuring.

**Particulate matter sensors** use light scattering of particles to estimate particle size. As particles travel through a cavity, the signal output is changed (through the interaction with the light path). The electronic components used (i.e. the diode and transistor), as well as the shape of the cavity, and the signal detection algorithm, are all factors that differentiate performance across sensor module brands (Giordano et al., 2021).

Potential limitations of particulate matter sensors include:

- For a given light wavelength, the scattered light intensity of a particle is approximately proportional to its size. Typically, red or infrared light sources are used, which are in the 670-980 nm wavelength range (Wang et al., 2015). Particles with sizes on the order of this wavelength generate a more linear response, however this becomes more complex beyond this range.
- Most of the time, individual particles are not measured; rather, the measurement is of a ‘population’ of particles. In some sensors (such as the OPC-3 Libelium), individual particles *are* measured, and assigned to a ‘size bucket’ based on a probability distribution (Giordano et al., 2021).
- Not all aerosols behave the same way; a particle’s light-scattering characteristic will affect how it will be sized. Humidity can also affect particle readings, as water droplets can be counted as particles (Giordano et al., 2021). **Error! Reference source not found.** shows electron microscope images of common particle types. Despite being of similar size scales (~5µm wide), they will have different optical-scattering properties, due to the difference in their shape/morphology. This is why co-location calibration is important, as the correction factors should represent the population of particles you intend to measure.



(a) Particle of biological origin, identified in the PM2.5-10
(b) Soot particle, identified in the PM2.5-10 (b)
(c) Cubic-shaped particle, identified in the PM2.5-10
(d) Particle characteristic of soil resuspension and particle possibly originated from anthropic sources, both identified in the PM2.5-10

*Figure 2. Scanning electron microscopy images of various particle types; image adapted from (Alvesa et al., 2015)*

***Answer to* Question 1: Why use such a low-accuracy specification for $NO_2$?**

Based on sensor limitations and third-party test reports, you can judge what a reasonable expectation of accuracy is for your sensor. Though not exact, conducting a research overview means your technical requirements are based on real-world data, which you can then adapt according to your data use case. Third-party test reports have shown that electrochemical gas sensors in low-cost devices typically have a variance of around 50%.

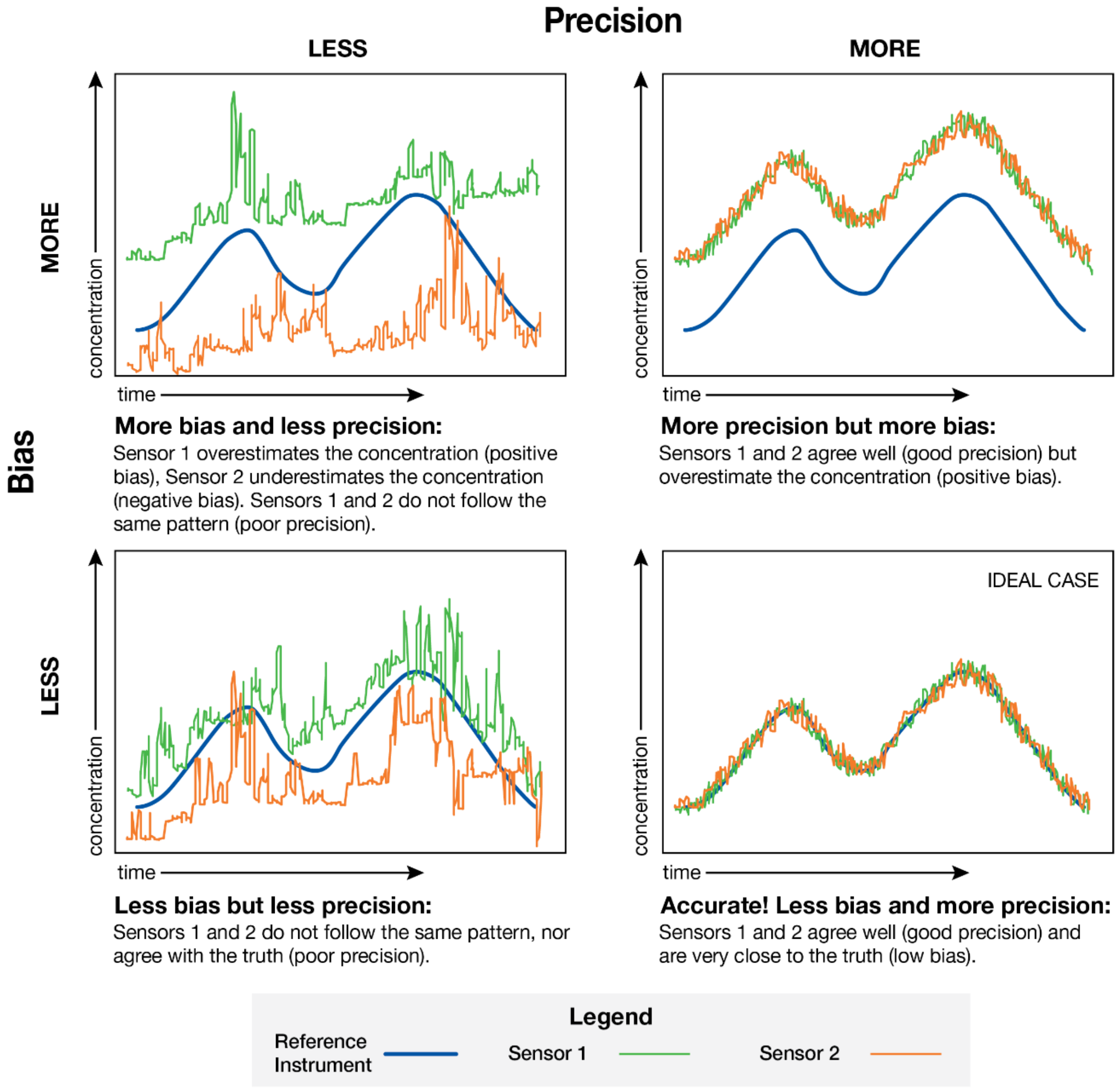
## Data sheets and statistics

Now that you are aware of the practical limitations of certain sensors, you can begin to determine which devices are most suitable for your project, and can meet your technical requirements.

This is where sensor/device data sheets and test reports are a valuable source of information. Before you read and interpret these documents, you will need a basic understanding of certain statistical terms:

- A measurement is accurate when the reading is *precise (has no variance), and there is no bias*
- A *bias* is when a measurement consistently over-reports or under-reports the true value
- *Precision* is a metric that describes how well the measurement reflects the trend of the true value.

Figure 3 shows a visual depiction of the concepts of bias, precision, and accuracy.



**More bias and less precision:** Sensor 1 overestimates the concentration (positive bias), Sensor 2 underestimates the concentration (negative bias). Sensors 1 and 2 do not follow the same pattern (poor precision).

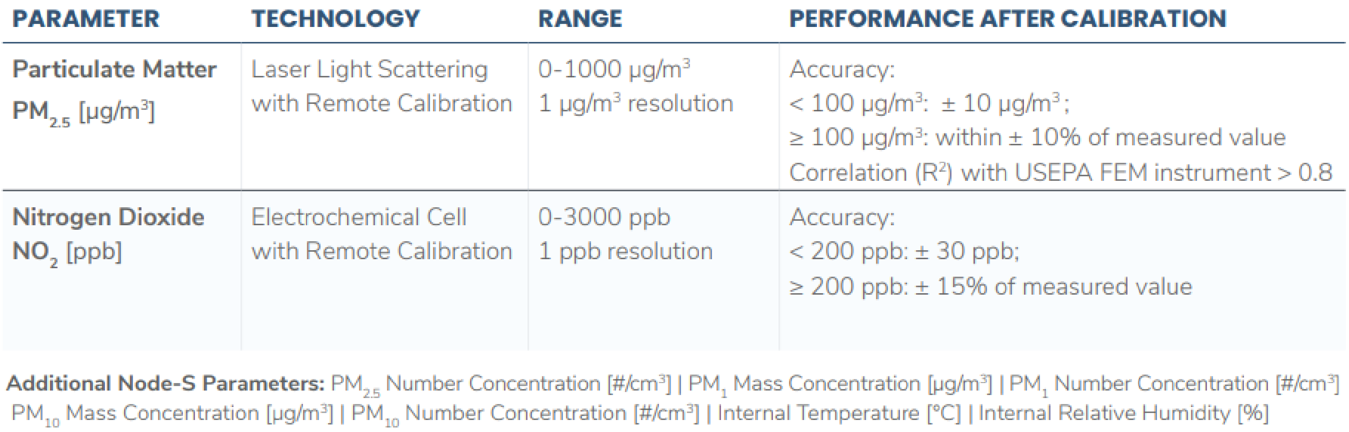
**More precision but more bias:** Sensors 1 and 2 agree well (good precision) but overestimate the concentration (positive bias).

**Less bias but less precision:** Sensors 1 and 2 do not follow the same pattern, nor agree with the truth (poor precision).

**Accurate! Less bias and more precision:** Sensors 1 and 2 agree well (good precision) and are very close to the truth (low bias).

*Figure 3. General statistical concepts, repurposed from (United States Environmental Portection Agency, 2022). Each graph visually depicts what a sensor reading might look like as we vary bias and precision. If a reading is accurate, it means it is both precise, and without bias. Figure source: United States Environmental Protection Agency*

The first place you can look for device specifications is on the device vendor’s website, where a data sheet and manual are usually available. Figure 4 shows this kind of data sheet (for the Clarity Node-S sensor).



| PARAMETER | TECHNOLOGY | RANGE | PERFORMANCE AFTER CALIBRATION |
|---|---|---|---|
| **Particulate Matter**<br>**$PM_{2.5}$ [µg/$m^3$]** | Laser Light Scattering with Remote Calibration | 0-1000 µg/$m^3$<br>1 µg/$m^3$ resolution | Accuracy:<br>< 100 µg/$m^3$: ± 10 µg/$m^3$;<br>≥ 100 µg/$m^3$: within ± 10% of measured value<br>Correlation ($R^2$) with USEPA FEM instrument > 0.8 |
| **Nitrogen Dioxide**<br>**$NO_2$ [ppb]** | Electrochemical Cell with Remote Calibration | 0-3000 ppb<br>1 ppb resolution | Accuracy:<br>< 200 ppb: ± 30 ppb;<br>≥ 200 ppb: ± 15% of measured value |

**Additional Node-S Parameters:** $PM_{2.5}$ Number Concentration [#/$cm^3$] | $PM_1$ Mass Concentration [µg/$m^3$] | $PM_1$ Number Concentration [#/$cm^3$] $PM_{10}$ Mass Concentration [µg/$m^3$] | $PM_{10}$ Number Concentration [#/$cm^3$] | Internal Temperature [°C] | Internal Relative Humidity [%]

*Figure 4. Excerpt from the Clarity Node-S sensor data sheet (Clarity, 2021). Accuracy and range are typically stated on device data sheets, but not in the detail required to make an accurate evaluation of whether the device is fit-for-purpose.*

Table 2 contains a breakdown of some of the specifications used in the Clarity Node-S sensor data sheet (in Figure 4).

*Table 2. Breakdown of data sheet terms from Figure 4*

| Parameter | Required specification |
|---|---|
| **Range** | The maximum and minimum readings the sensor can measure. |
| **Resolution** | The minimum increment the sensor can read. |
| **Accuracy** | Note: there are two specifications here. For example, look at $PM_{2.5}$ – *under* 100 µg/$m^3$, the reading can be off by +/- 10 µg/$m^3$. This means that if the reference monitor records a concentration of 15 µg/$m^3$, the Clarity Node-S can read anywhere between 5-25 µg/$m^3$. *Above* concentrations of 100 µg/$m^3$, the accuracy error changes to a percentage. This means that for a measurement of 110 µg/$m^3$, the Clarity Node-S can read anywhere between 99-121 µg/$m^3$. |
| **$R^2$** | This data sheet also states the sensor's $R^2$ value, which is uncommon for sensor data sheets (Clarity has had a third party, AQ-SPEC, evaluate its sensors in the field). $R^2$ value is the correlation coefficient, and indicates the rate of agreement with another sensor, which often uses the federal equivalent method (FEM). The value ranges from 0 (no correlation) to 1 (full agreement), and typical values for low cost sensing devices lie in the 0.5 to 0.9 range.<br>Note: this is not the final metric by which you should judge a sensor. See the discussion below for a more detailed explanation. |

While there are useful specifications provided in this data sheet, keep in mind that you may need to seek out additional contextual information to build a full picture:

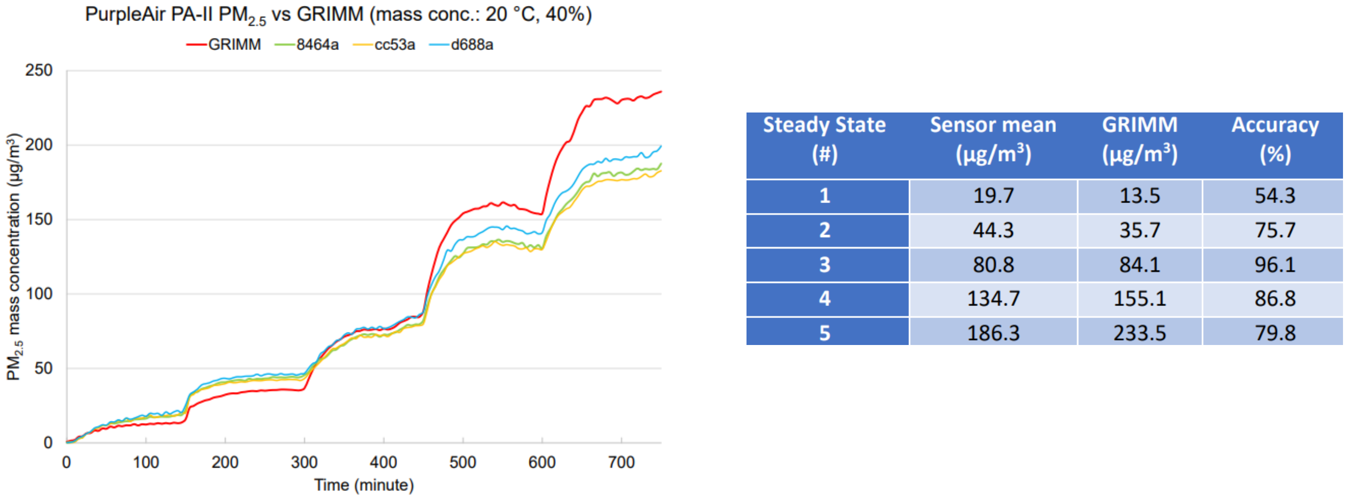
- We do not know the conditions under which the co-location with the FEM was performed. The stated $R^2$ value of 0.8 may not be achieved with a different humidity/temperature and particulate population profile. We also do not know what range of pollution the FEM in the co-location process measured, or what type of reference instrument it was.
- The $R^2$ and accuracy specifications are from *after* Clarity's retrospective calibration has taken place. Keep in mind that Clarity is unique in the market in providing this service, and this specification is not available in most data sheets. Should you co-locate your own Clarity S-Node device in the field, you will mostly likely obtain a lower $R^2$ value prior to Clarity's calibration service. Even when adjusted the value will differ to that on the datasheet depending on the variations in temperature, humidity and particulates unique to your local environment.
- In reality, the accuracy specification within a certain range will change. You could take +/-10 µg under 100 µg/m$^3$ at face value, but that specification may be different at the lower, mid, and upper range of that boundary.
- The data sheet specifies that $PM_{1.0}$ and $PM_{10}$ modules are available, but there are no specifications for these readings.

**TIP:** Third-party co-location results can be very useful. However, you should understand that your own co-location results will most likely differ from any third-party results. This is because the environmental conditions will be unique to your chosen location.

Figure 5 shows a different example of a test report, from tests performed on the PurpleAir PA- II sensor by AQ-SPEC. These tests were done under temperature- and humidity-controlled lab conditions, and compared with a FEM (South Coast Air Quality Management District, n.d.-c).

The table in

Figure 5 shows that accuracy varies across the measurement range (up to 100 µg/m$^3$). Despite the data sheet saying that the variance will be +/-10 µg on the measurement made, in reality, the true figure could be better or worse (in this case, it is better). Using these results, you can form a clearer understanding of what your sensing device is capable of, within your concentration range of interest.



| Steady State (#) | Sensor mean (µg/m³) | GRIMM (µg/m³) | Accuracy (%) |
|---|---|---|---|
| 1 | 19.7 | 13.5 | 54.3 |
| 2 | 44.3 | 35.7 | 75.7 |
| 3 | 80.8 | 84.1 | 96.1 |
| 4 | 134.7 | 155.1 | 86.8 |
| 5 | 186.3 | 233.5 | 79.8 |

*Figure 5. PurpleAir PA-II Lab test results, repurposed from South Coast Air Quality Management District AQMD (n.d.-a). From left to right: A) A graph of increased $PM_{2.5}$ concentration, increasing in steps over time. Here you can see that the three purple air sensors start to notably deviate from the reference, above a concentration of 100 ug/$m^3$. B) This table shows the change in accuracy in different concentration bands, compared to the reference instrument. Figure source: Purple Air*

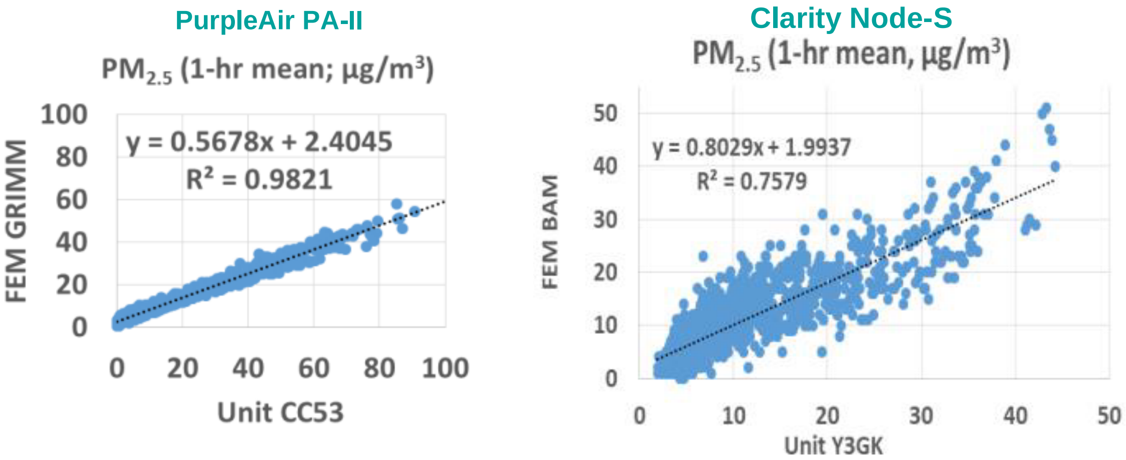
$R^2$ plots are a good way to visualise bias and precision at the same time. In Figure 6, we compare PurpleAir PA-II (South Coast Air Quality Management District, n.d.-a) and Clarity Node-S (South Coast Air Quality Management District and Air Quality Sensor Performance Evaluation Centre, 2018) field test results, as reported by AQ-SPEC.

PurpleAir PI-II has a higher $R^2$ value than the Clarity Node-S, shown in the graph as a line that better follows a 1:1 ratio on both axes. There is less variance (less spread of data points), indicating higher precision.

However, there is still a positive bias: when the reference reads 20 µg/$m^3$, the PurpleAir PI-II reads ~30 µg/$m^3$. This will be easy to correct for, as there is a clear relationship. The Clarity Node-S has higher variance, and a slight positive bias (even if you correct for it, the output would still have a large error swing). One factor to note is that the reference instruments used are different: the GRIMM is an optical sensor and is more likely to align with other optical sensors, whereas the BAM (beta attenuation monitor) uses beta ray attenuation to measure the particle mass.

***Answer to* Question 2: Why focus only on the range between 100-240 ppb (instead of 0-240 ppb)?**

Accuracy can vary across the concentration range limit. In the hotspot identification example (see Table 1), we are not too concerned about the lower range of the measurement reading. This relaxes our requirements, and makes it easier to find a suitable sensor.


PurpleAir PA-II

Clarity Node-S

*Figure 6. PurpleAir PI-II (left) and Clarity Node-S (right) field test results against the FEM GRIMM and FEM BAM. Repurposed from (South Coast Air Quality Management District, n.d.-a) and (South Coast Air Quality Management District, n.d.-b).*

## Existing performance evaluation reports

As previously discussed, vendor data sheets provide a high-level overview of the performance of a sensing device. Third-party reports are another useful source of device performance information as they can give a better idea of what kind of performance to expect, however they should be taken as indication only as:

- Information on the test environment is not always included- there is no guarantee you would get similar results at a different time of year, in a different location
- If there is high inter-variability between devices of the same brand, it
- The dataset produced from testing will likely not be provided – as such, any calibration coefficients obtained from co-location data will not be available for you to use, and depending on the inter-variability between devices, will likely not be applicable to the device you have anyway

There are a variety of third-party reports on sensor performance available, with varying degrees of detail (United States Environmental Portection Agency, 2022). Reliable sources for these reports include:

- U.S. EPA’s Office of Research and Development
- California’s South Coast Air Quality Management District (South Coast AQMD) Air Quality Sensor Performance Evaluation Center
- European Commission Joint Research Centre
- Airparif AIRLABS Microsensors Challenge
- academic researchers
- device vendors and sensor manufacturers.

Keep in mind that evaluations in the field will not necessarily reflect the sensor performance you will get in your test location. Outdoor conditions cannot be controlled or replicated: pollutant concentration, mixture, and environmental conditions are all constantly changing. This means that you should not expect the exact same performance results in any co-location test you carry out. Results from a co-location test held during a Californian summer, for example, will be quite different to those from a co-location test in the Blue Mountains in mid-winter.

Conversely, lab tests give some insight into how sensors perform under specific, controlled environmental conditions. These tests are more expensive (due to the equipment involved), but may be necessary in order to create test conditions you will not easily find outdoors (for example, high concentrations of some gases).

## Evaluation process

The evaluation process is one that should not be taken lightly, as the decision you make could result in significant expenditure of time and resources. A certain minimum investment of resources is needed to determine whether sensor specifications will meet your project's technical requirements.

The flow chart in Figure 7 contains a decision tree on the evaluation process (taken from the U.S. EPA's *Enhanced Air Sensor Guidebook*).

This next step will be useful if you have already selected a set of sensors to evaluate, and you have read the device's data sheets (and any other documents the manufacturer has supplied). If you find that this information is insufficient in terms of helping you decide if the sensor is appropriate for your project, use this flow chart to determine the best process for gaining the necessary information.

This may lead to conducting further research to find third-party evaluation reports or published papers, contacting the manufacturer, or co-locating/testing the device yourself.

***Answer to* Question 3: How is it possible to know if specific sensors meet project requirements, and where can that information be found?**

There are many sources where you can find reliable performance evaluations of sensors. These include reports by government and research institutions, and peer-reviewed journal articles. If you cannot find this information, you may choose to evaluate a specific sensor yourself, or select another device that has in-depth test reports.

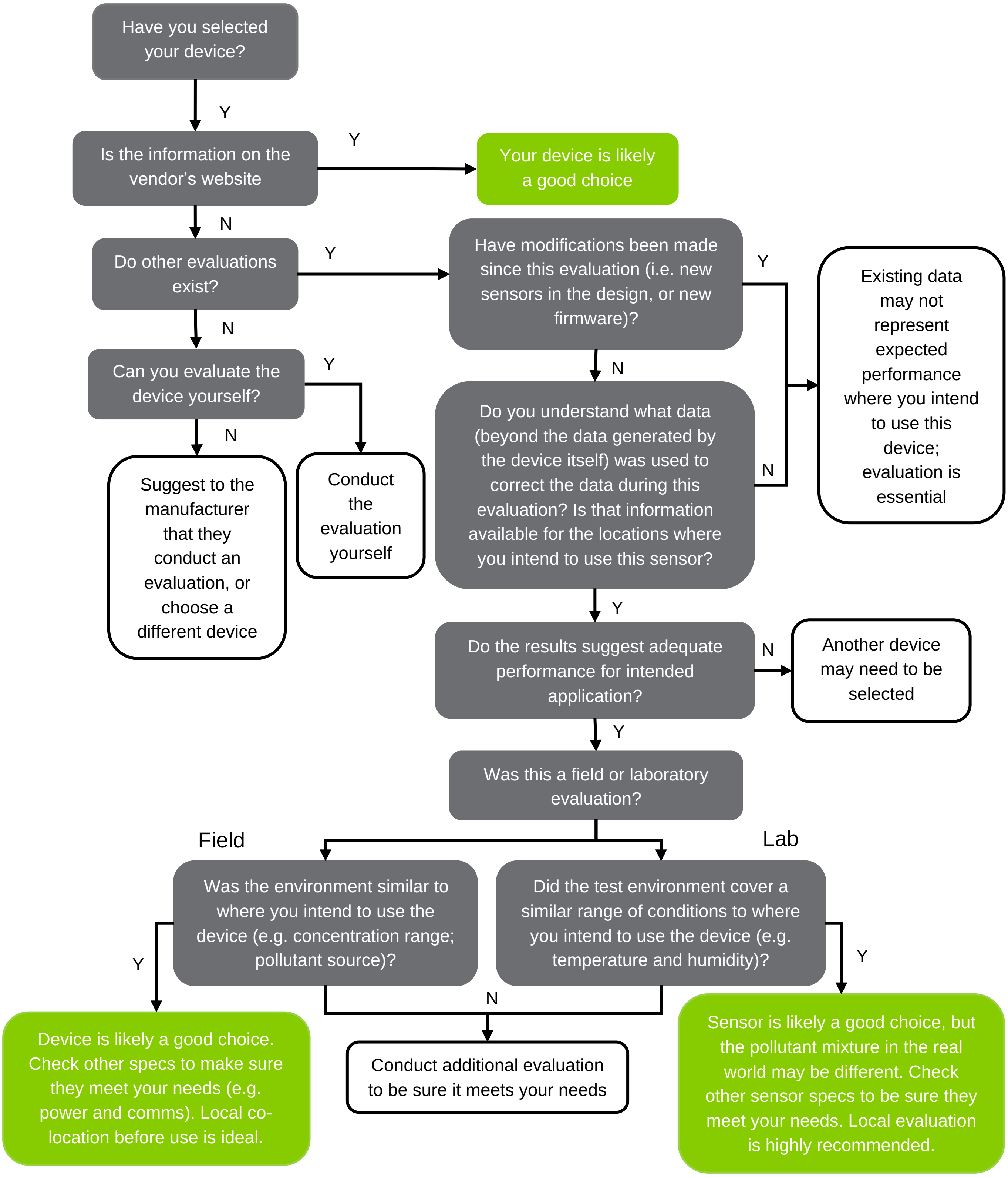


*Figure 7. Evaluation decision flow chart, repurposed from (United States Environmental Portection Agency, 2022). This is a comprehensive guide to help you decide whether you need to seek more information, develop your own evaluation report, or deem your device suitable for use (based on existing information).*

## Co-location testing of your devices is strongly recommended

It is strongly recommended that air quality devices be co-located and calibrated in the field against a reference monitor. Manufacturers can provide advice on when to co-locate, as this may vary (depending on which pollutants are being measured). State government environmental agencies can also provide assistance.

Without this co-location process, you risk having no visibility on what the true performance of your selected air quality device is – and this can negatively affect your project outcomes. Make sure you allocate sufficient time and resources for co-location early in your project planning. See the OPENAIR Best Practice Guide chapter *Sensing device calibration* for more information on this process.

**TIP:** It is strongly recommended that you co-locate your sensors, regardless of how much information about their performance is available. You will not have access to the data sets that third-party testers have obtained, and nor will these data sets necessarily be relevant to your own sensing network (as co-location results are specific to the test location). When you co-locate your sensors, you will be required to generate a data set to understand how accurate/inaccurate your sensors are, and which correction factors to apply.

## Other device parameters

Once you have evaluated the performance of various sensors, you may find that there are multiple devices that could be suitable to your project. In this case, other device parameters can be used to help you make your final decision. These include communications, power source, customer service, documentation quality, and cost.

***Answer to* Question 4: What about other sensor parameters, such as power, communications, and software interfaces?**

These device parameters are important to consider, as they may affect your project resources, and there are practical constraints in these areas that limit the options available. This OPENAIR resource focuses predominantly on sensor performance evaluation. Refer to the companion Best Practice Guide chapter: *Sensing device procurement,* which discusses these other factors.

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# Associated OPENAIR resources

## Best Practice Guide chapters

### *Sensing device procurement*

This Best Practice Guide chapter provides guidance on the selection and procurement of smart low-cost air quality sensing devices. It explores critical considerations relating to the design and functionality of devices and the quality of the data they produce, supporting procurement choices that are appropriate to the needs of a project and organisation.

### *Sensing device calibration*

This Best Practice Guide chapter provides guidance on the calibration of smart low-cost air quality sensing devices. It discusses calibration, co-location, decision-making, and developing and following a plan.

## Supplementary resources

### *Identify template*

This template supports creation of a business plan and 'data use action statement' as strategic foundations for a smart low-cost sensing project.

### *A framework for categorising air quality sensing devices*

This resource presents a new framework for categorising air quality sensing devices in an Australian context. It identifies four tiers of device types, separated in terms of functionality, and the quality and usability of their data output. It is designed to assist with the selection of devices that are appropriate to meeting the needs of a project and an intended data use case.

### *Technical requirements template*

This template is an extended, step-by-step tool that supports the development of technical requirements for a smart air quality monitoring project. These requirements define the details of technologies (sensing devices, platforms, and services) that can meet the specific needs of a project, and are intended to support procurement decision-making.

### *A guide to developing technical requirements*

This resource is a companion guide to the technical requirements template.

# Further information

For more information about this project, please contact:

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This supplementary resource is part of a suite of resources designed to support local government action on air quality through the use of smart low-cost sensing technologies. It is the first Australian project of its kind. Visit www.openair.org.au for more information.

OPENAIR is made possible by the NSW Government’s Smart Places Acceleration Program.

Document No: 20231207 Sensing device performance evaluation methodology SR202 Version 1 Final