Key considerations for future projects from the stationary network

Installing a new dense network of lower-cost monitors can be challenging because there are numerous site-specific logistical issues and permissions which need to be resolved before full deployment can take place. Lower-cost sensors have some inherent technology limitations that can vary by system and by sensor, and it is only possible to identify and address these by implementation of networks in long-term monitoring studies like Breathe London.

It is important to select suitable low-cost sensor systems which can make rapid one-minute measurements in order to support new network calibration approaches that could transform air quality monitoring methods of the future. In addition, the species selected for measurement should not be restricted to just regulated compounds which are monitored at reference instrument sites. The new technology may be exploited further by incorporating sensors which can detect tracer molecules such as CO_2 thereby delivering vital new information on pollution source apportionment.

Below is a summary of key issues and considerations found during deployment, which should be accounted for when planning similar hyperlocal stationary monitoring at other locations.

Sensors and equipment

Installation

The time and resources to obtain permissions to install monitors should not be underestimated. Local knowledge and political buy-in, as well as access to ideal siting locations such as lampposts with mains power supply (including the correct sockets), can streamline this process. Depending on location, installation may require outside contractors, increasing the budget and creating time constraints.

AQMesh pod installed on a lamppost with mains power supply. Credit: ACOEM Air Monitors.

Sensor technology

Lower-cost sensor technology is rapidly evolving, and both sensor manufacturers and sensor system manufacturers frequently upgrade their products sometimes without making this process completely transparent. This is very common in the present market but can create complications such as when a manufacturer's firmware algorithm is updated, which can impact on the data quality, or when sensor models are discontinued and replaced with upgrades during the lifetime of the project. It is recommended that projects proactively ask manufacturers about planned product updates during the procurement process and keep stocks of suitable replacement sensors.

Network performance

Overall, the Breathe London network performance maintained a high operational rate between March 2019 and June 2020 with more than 80 pods in the network reporting at least 75% valid hourly data (see **Figure 2**). The increase in number of active pods with valid data in early 2019 reflects correcting power supply and other performance issues in the early months of deployment. This demonstrated how vital it is to get as much information as possible on sensor performance ahead of procurement, as well as incorporating time to test and validate instrumentation. Sensor replacement and pod maintenance costs are also key considerations for understanding the overall project budget.

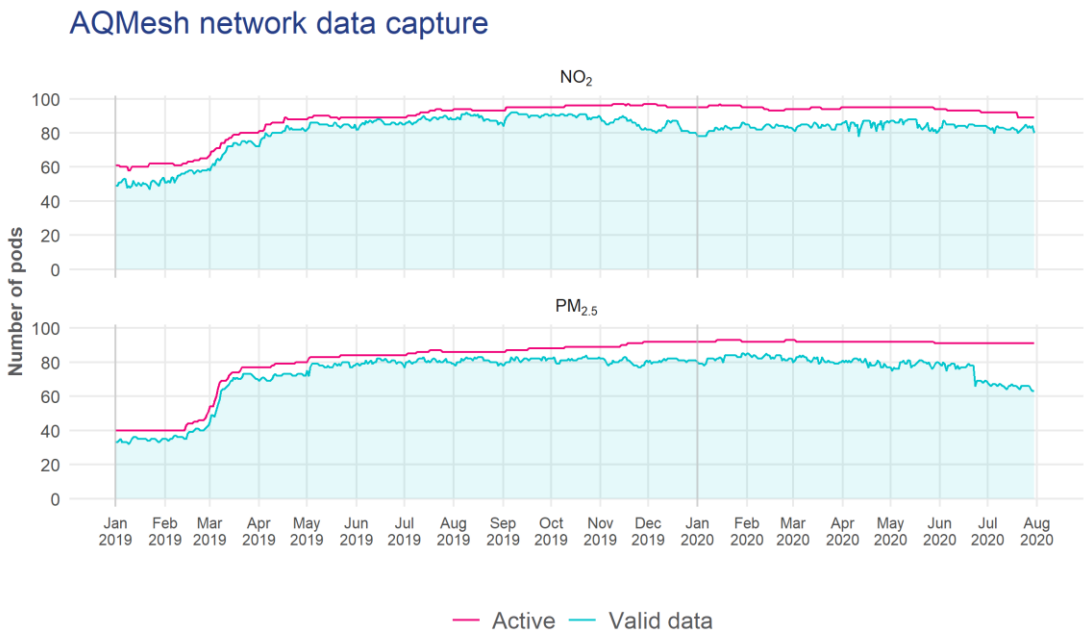

FIGURE 1. Number of AQMesh pods with > 75% valid hours of NO_2 or $PM_{2.5}$ data each day (blue line). Also shown is the maximum number of operating or active pods in the network (red line). Note that the coverage criterion is met for generally over 80% of the instruments deployed although some degradation is seen later in the project in June 2020 for $PM_{2.5}$

Monitoring plan

Siting logistics

Logistical needs are a vital consideration when choosing the location of monitors. Requirements such as pod power, weight, and height should be clearly documented to streamline communication between the project and potential hosts when determining the suitability of sites. For example, the pods used in Breathe London needed sufficient power, so potential sites either required adequate sunlight for installing solar panels or the ability to plug into mains, both of which have cost and logistical implications.

Microscale siting

Positioning of the pods can potentially impact the representativeness of the measurements. Due to the limited options for mounting pods on buildings or street furniture, large networks may have to compromise on locations. To assess possible sampling issues at sites that did not follow siting guidelines set out in the European Union (EU) directives for reference instruments, a microscale siting study was conducted at three sites to better understand the potential effect of pod siting (see Appendix 2). This showed the effects to be minimal, at least for the sites tested, so that an important point of lower-cost, small sensors is that they can in fact be sited in places that are impossible for traditional reference instruments, generally outweighing potential disadvantages associated with microscale siting.

Data quality assurance and quality control

Pre-deployment co-location at reference monitoring sites

Ideally, adequate time should be built-in prior to deployment to ensure that all sensors can be co-located at reference sites representative of their ultimate placement location and that as many pollutants are measured by the system as possible. However, a key output from the Breathe London project was the cloud-based network calibration methodology which yielded results comparable to physical co-location. It is highly recommended that future projects test the performance of at least a subset of the sensors to be deployed in order to address any unexpected compatibility or suitability issues.

Designated gold pods and spare pods

A valuable capability is the ability to move a subset of pods within the network based on project needs. Designating a subset of pods for gold pod calibrations or as transfer standards will help maintain network performance and for testing and validating any cloud-based calibration methodology. It is recommended that future projects consider maintaining several calibrated, spare pods to allow anomalous sites to be investigated or to replace the pods in the network that have been otherwise rendered inoperable to ensure continuity. The ability to move spare pods within the network can determine

whether atypical results are a data/measurement issue or local air pollution issue (i.e. potential hotspot).

Long-term co-location at reference monitoring sites

Although the cloud-based network calibration method is an important basis for maintaining the calibration and QA/QC of the lower cost network, co-locating one or more pods with a reference monitor for an extended period (i.e. many months), or repeated co-locations, can provide insights into the performance of the lower-cost sensor network. For example, such co-locations during Breathe London enabled evaluation of performance issues, including identification and correction of a gradual upward drift of NO_2 measurements associated with an O_3 cross interference. In this context, access to multiple reference sites spanning different site types could be of value.