S1. QUANT main study devices

In this section, a brief description of the QUANT main study systems' components is offered.

PurpleAir (PA) (https://www2.purpleair.com) devices (PA-II-SD model, firmware v4.11) reports particulate matter (PM_1, $PM_{2.5}$, and PM_{10}), and it was chosen for its penetration around the world. Two identical Plantower PMS5003 (Plantower) sensors (channels A and B) are found in each PA. It offers two data products (2-min avg. time): the "cf_atm" (for outdoor applications) and the "cf_1" (for indoor or controlled environment applications). The PMS behaves like a nephelometer rather than an optical particle counter to measure the light scattered by the PM (Ouimette et al., 2022) and is composed of a laser, a photodiode, a fan, and a microprocessor control unit. They also measure temperature (Temp), relative humidity (RH), and atmospheric pressure (Pres) (Bosch). The data can be communicated via Wi-Fi or stored locally (microSD card), which was the preferred way during the colocation. No calibrated products are offered by the company.

AQMesh (https://www.aqmesh.com) reports NO_2, NO, O_3 using electrochemical (EC) sensors (Alphasense), CO_2 with a non-dispersive infrared sensor (NDIR, Alphasense), PM_1, $PM_{2.5}$, and PM_{10} through a light-scattering sensor (Nephelometer, Environmental Instr.) with 1-minute time resolution (algorithm v5.1 for gases and v3.0 for PM). This instrument also registers Temp, RH, and Pres (Solid-State sensors) (Zauli-Sajani et al., 2022) and the sampling mechanism employs a pump. The collected data is sent to the company server via a cellular network and post-processed (Temp, RH, and cross-interference correction) in the cloud by a proprietary algorithm. Finally, the data is released to the final user via secure web login or through its Application Programming Interface (API). Although the first 4 months of the deployment the data had a 15-min resolution, since then the provided resolution is 1-min average.

AQY (v.1.0) is also a multi-species device (https://www.aeroqual.com) and measures O_3, NO_2, $PM_{2.5}$, PM_{10}, Temp, and RH. This is the only device system that does not use Alphasense sensors for gases. While O_3 is quantified using a metal oxide sensor (WO_3-based, Aeroqual Ltd), the NO_2 is measured by an EC sensor (Membrapore type O_3/M5, Aeroqual Ltd) (Weissert et al., 2019). For PM it uses a light scattering method (Nova) to convert size and particle count to a mass fraction and behaves like a nephelometer (Myklebust et al., 2022). These LCS devices send their data (1-min time resolution) to the Aeroqual server via cellular (WiFi could also be used for this purpose) or stored locally (microSD card). The non-local data access is through a web portal or via API.

Zephyr units (https://www.earthsense.co.uk) measure PM (Nephelometer, Plantower), Temp & RH (Sensirion), and Press (Bosch) (the sample uptake uses a fan). As most of the commercial units tested here, it used Alphasense EC sensors (the "A series", a smaller version than the B series) for gases (NO, NO_2, and O_3). These devices send their raw data to the server via a cellular network, where they pre-process the raw signals. We have secure access to the measurements with a time resolution of 1-min per species through the website or via its API.

ARIsense v200 devices (https://quant-aq.com) measure NO, NO_2, O_3, CO (EC, Alphasense), CO_2 (NDIR, Alphasense), Temp & RH (Sensirion), and Press (Bosch) (Cross et al., 2017). Of all the devices tested, this is the only one that uses an Optical Particle Counter (OPC) for PM (Particles Plus). Communication is carried out through a cellular network and the data products are accessed through a web portal or API (1-minute time

resolution). According to the company policy, only the gas data products are subjected to calibrations (if colocation data is available).

S2. WPS devices

A short description of the WPS devices' components is shown in this section

Modulair-PM instruments (https://quant-aq.com) employ two different techniques to obtain PM mass concentration (it samples the air using a fan), an OPC (Alphasense, OPC-N3) and a nephelometer (Plantower, PMS5003). This system provides 1-min time resolution data for PM_1, $PM_{2.5}$, and PM_{10}, plus size-resolved particle number concentration (range 350 nm to 40 µm) (Meyer et al., 2022; Westgate & Ng, 2022). Temp, RH, and Press are also measured, but no data was found about the sensing elements it uses. The post-processed data can be accessed locally (microSD card) or through its server (cellular network comm) via its web portal or API.

AQMesh (see earlier description).

The Atmos device (http://urbansciences.in/) reports PM_1, $PM_{2.5}$, PM_{10} (Plantower, PMS7003) plus Temp and RH (Adafruit), employing a fan as a means to sample the air. The system transmits the data (1-min time resolution) to a cloud server (only via Wi-Fi) and also stores it locally (Puttaswamy et al., 2022). The data can be accessed via a web dashboard or API. Unfortunately, and due to the meteorological conditions at the Manchester supersite these co-located devices only survived for about 2 months.

The IMB instrument (https://www.bosch-mobility-solutions.com) measures NO_2, O_3 $PM_{2.5}$ and PM_{10}, (Alphasense sensors), plus Press, RH y Temp (no details were found about the type/brand/model). The raw data is transmitted to their cloud using cellular connectivity (3G or LTE). The final data is 1-min resolution (accessed only via API).

Polludrone (https://oizom.com) uses Alphasense sensors for gas measurements (B4 series for NO, NO_2, O_3. No data available about CO, CO_2 and SO_2) and a Wuhan Cubic PM3006S for PM ($PM_{2.5}$ and PM_{10})(*Oizom - Polludrone Smart*, n.d.). It also registers RH and Temp, but no data was found in regards to sensor model/brand. The sampling mechanism uses a fan and data transmission is wireless. The final product (time res is 10-min) can be obtained through the Oizom webpage and/or via API.

Kunak Air Pro (https://www.kunak.es/) uses a fan for sampling and all sensors are from Alphasense (EC, B series for CO, NO, NO_2 and O_3; an NDIR sensor for CO_2; and an OPC-N3 for PM_1, $PM_{2.5,}$ and PM_{10}) (Hofman et al., 2022). It also provides Temp, RH, and Press (no data was found in regards to environmental sensor model/brand). The raw data is transmitted via a multi-band network, and the final data (time res is 5-min) can be accessed through their website or via API.

The Silax Air (https://vortexiot.com) system measures NO_2, O_3, PM_{10} and $PM_{2.5}$. Their webpage mentions that for PM an optical scattering sensor is used and EC sensors for the gases. Further details weren't found. The raw data is transmitted via 4G or WiFi and the final user accesses the final product (5-min time res) through API or website.

The Node-S system (https://www.clarity.io) holds a nephelometer (Plantower PMS6003) to measure 3 PM size cuts (PM_1, $PM_{2.5}$, PM_{10}) (Liu et al., 2022) and EC sensors for NO_2 (Alphasense) (Miech et al., 2021). The air is dragged into the system by a fan and a Bosch sensor is used for press, RH, and temp. The data is communicated to Clarity's cloud via cellular signal (4G) and the final product is ~3-min time res (something unusual for sensor systems). Access to the final data is via the web portal or through API.

Praxis/Urban (https://www.southcoastscience.com) system employs EC sensors for NO, NO_2, O_3 (Alphasense, A series), an NDIR for CO_2 (Alphasense), and particle counter (Alphasense, OPC-N3) for PM_1, PM_{10} and $PM_{2.5}$. The Temp/RH is Sensirion and the Press sensor is TDK. The raw data is communicated to the company server using 4G and the user can access it and post-processed data through an API (1-min time res).

S3. Co-location sites

For the main QUANT deployment, 3 field sites were chosen: Manchester, London, and York, all providing extensive reference measurements across a range of chemical environments representative of UK urban atmospheres. On the other hand, only the Manchester site was used for the WPS colocation.

The Manchester Air Quality Supersite (MAQS, 53° 26' 39.2"N, 2° 12' 51.9"W) is one of the largest air quality research facilities in the UK, and also because it is located in the south of the city of Manchester (the second largest metropolitan area in the UK, with approx. 3.3 million inh.) in an urban background environment (avg. temp. in winter of about 4-5 °C and RH ~87 %, avg. temp. in summer around 16-17 °C and RH ~88 %. MAQS reference instrumentation details can be found in the Section S4. All the data provided by MAQS was 1-min time resolution.

The London Air Quality Supersite (LAQS) is an urban background monitoring site located at Honor Oak Park (51° 26' 58.9"N 0° 02' 14.6"W) in Greater London, the third biggest European urban conglomeration with approx. 14.8 million inh. (avg. temp. in winter ~5 °C and RH ~84 %, avg. temp. in summer ~17 °C and RH ~72 %). All gas data provided by LAQS is 1-min time resolution and 15-min for PM.

The York Fishergate roadside site (YoFi), located in the city of York (~210,000 inh., avg. temp. in winter of ~4 °C and RH ~87 %, avg. temp. in summer around 15 °C and RH ~80 %). This site is a self-contained air quality monitoring station located very close to the city centre on a traffic island (53° 57' 06.9"N 1° 04' 33.1"W) surrounded by a residential/commercial area. This site was chosen to evaluate the LCS responses to a greater pollutant variability typical of traffic-related sites (in contrast with urban background monitoring stations as in the case of MAQS and LAQS). While PM and NOx data from YoFi are 1-hr time resolution, the O_3 data is 1-min (deployed on the 15th of May 2020, specifically as part of the QUANT study).

S4. Reference instrumentation, QA/QC, and data-sharing periods

Table S1 summarises the reference instrumentation at each site, Table S2 describes some of the QA/QC processes at the supersites, and Table 3 shows the data periods shared with the suppliers.

Table S1. Research grade instrumentation used for the QUANT study.

Analyte	Manchester	London	York
NO	Thermo 42i-y (Chem)	Teledyne T200U (Chem)	Teledyne T200UP (Chem)
NO_2	*Teledyne T500U (CAPS)	*Teledyne T500U (CAPS)	
O_3	*Thermo 49i (UV)	*Teledyne 400E (UV)	*2B 205 (UV)
PM	*Palas FIDAS200 (OAS)	*Palas FIDAS200 (OAS)	*Met One BAM 1020 (BA)

*Equivalent to reference

Acronyms: Chem: Chemiluminescence; CAPS: Cavity Attenuated Phase Shift Spectroscopy; UV: Ultraviolet; OAS: Optical aerosol spectrometer; BA: Beta attenuation.

Table S2. Summary of Quality Assurance processes in MAQS and LAQS

Instrument	Frequency	*Process
NO_y	At least monthly	Zero and span checks using standard cylinder and scrubber. Corrections to zero and span values.
NO_2	Daily	Automatic zero and span checks using internal NO_2 diffusion tube and scrubber. Zero corrections, span monitored.
O_3	Daily	Automatic zero and span checks using internal O_3 lamp and scrubber. Corrections to zero, span monitored.
CO	Every three hours & monthly	Zero checks every three hours and span checks monthly using onsite cylinder. Adjustments to zero and span values.
CO_2 and CH_4	Regular	Stability checks using onsite cylinder, no corrections made.
*PM	Semiannual	Sizing response verified with Mono dust, flow rate checked with Gilibrator.

*Checked with external standards by NPL every 6 months. These external standards are also used to provide a certification of the on-site standard cylinders. Final corrections to the data are provided by using the audit data to define the concentration of the on-site standards, with zero and span values interpolated between the calibration points.

**Sizing and flow checked every 6-month NPL audit process.1

Table S3. Reference data is shared with the sensor manufacturers.

QUANT main study			Wider Participation Study		
Reference dataset	**Period**	**Released**	**Reference dataset**	**Period**	**Released**
1	10-12-2019 - 17-02-2020	15-04-2020	**1**	17-06-2021 - 16-07-2021	23-07-2021
2	18-02-2020 - 17-08-2020	27-10-2020	**2**	01-12-2021 - 31-12-2021	26-01-2022

3	18-08-2020 - 17-02-2021	15-04-2021	**3**	01-05-2022 - 31-05-2022	15-06-2022

S5. Data products

Figures S1 and S2 summarise data products crafted during QUANT and the WPS according to the company.

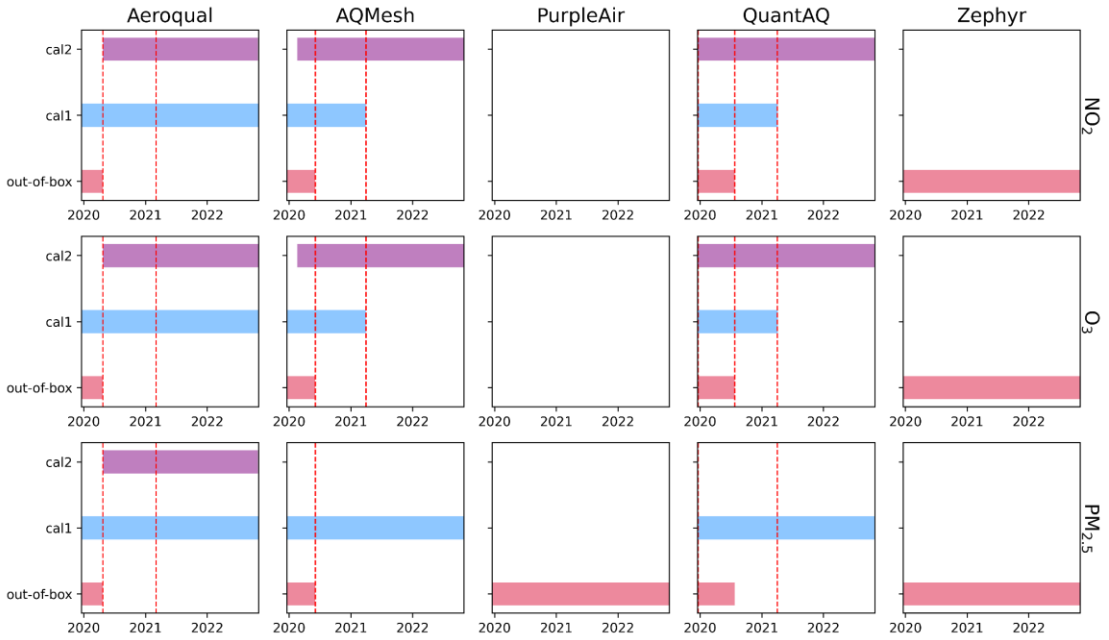

Figure S1. Data product for each of the participating companies during Main QUANT. The top panels are for NO_2, the middle panels for O_3 and the bottom panels for $PM_{2.5}$. The y-axis represents the different products: "out-of-box", cal1 and cal2. The x-axis shows the dates for which each company provided the mentioned products.

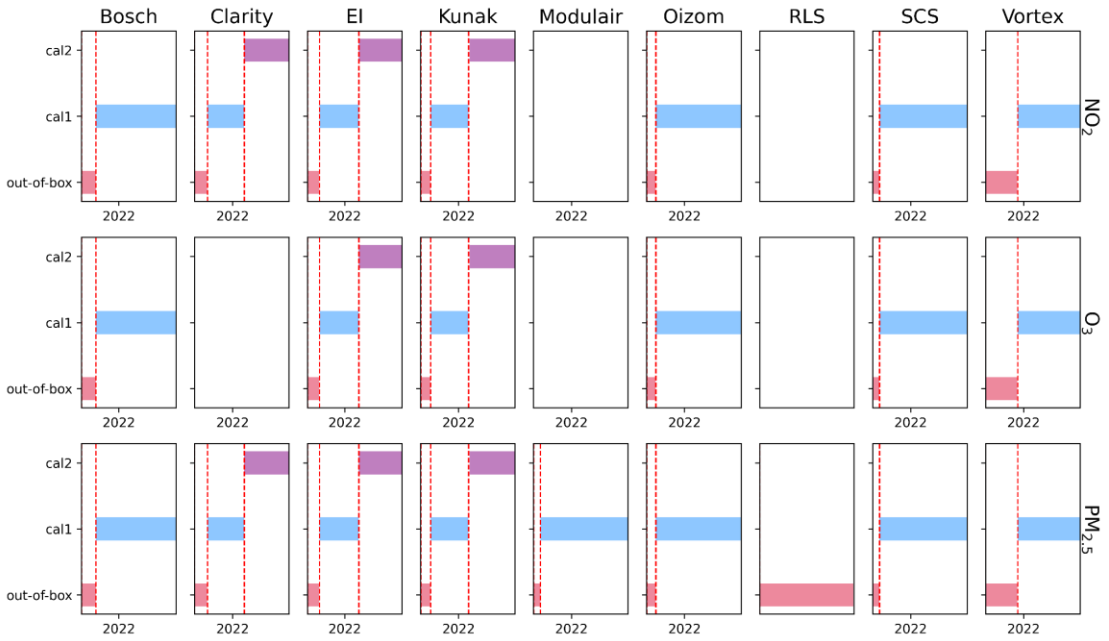

Figure S2. Data product for each of the participating companies in the WPS. The top panels are for NO_2, the middle panels for O_3 and the bottom panels for $PM_{2.5}$. The y-axis represents the different products: "out-of-box", cal1 and cal2. The x-axis shows the dates for which each company provided the mentioned products.

S5. Sensor performance estimated using different reference methods

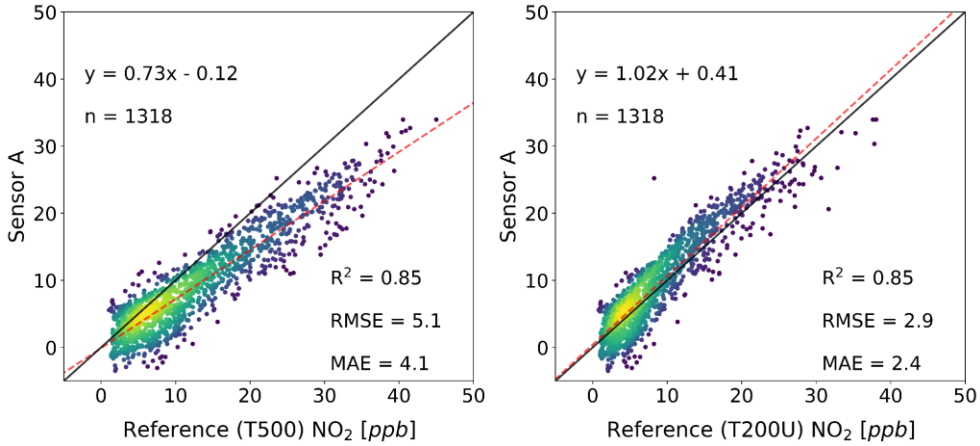

Figure S3. Comparative analysis of "Sensor A" performance against two reference instruments for NO_2 measurements. The left plot shows the correlation with the Teledyne T500 (Cavity Attenuated Phase Shift Spectroscopy), while the right plot is against the Teledyne T200U (chemiluminescence) and specifically installed at the Manchester supersite for the QUANT study. The dashed red line represents the line of best fit for the sensor data against each reference, indicating a closer agreement with the T200U (slope=1.02) compared to the T500 (slope=0.73).

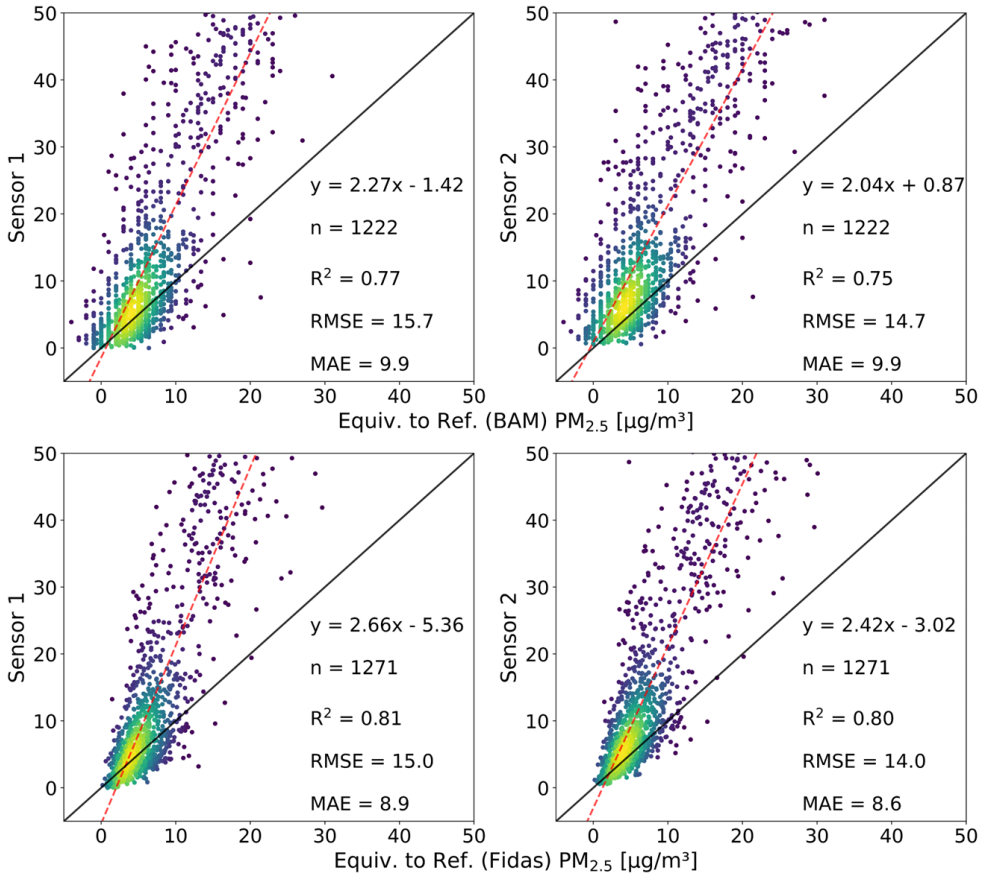

Figure S4. Comparative regression analysis and performance metrics of two distinct $PM_{2.5}$ sensor systems benchmarked against a BAM for the top plots and a Fidas for the bottom plots. Each plot demonstrates the correlation and agreement between the sensor readings and the two equivalent-to-reference instruments in a roadside site located in York.

S6. NO_2 Diffusion tubes

A diffusion tube co-location study was carried out between November 2020 and November 2021 at the MAQS, LAQS and York sites, using two types of diffusion tubes: the conventional (also known as LAQM, for Local Air Quality Management) and UUNN (for UK Urban NO2 Network). LAQM tubes have an open end and capture NO_2 which is converted to nitrite when reacting with triethanolamine (TEA) for subsequent analysis. On the other hand, UUNN tubes, similar in the sampling process to LAQM, include an amorphous polyethylene filter at the open end to further mitigate the effect of wind on NO_2 measurements. For more details refer to (Butterfield et al., 2021). Both types of tubes (conventional and UUNN) were installed in duplicates, either in shelters (to limit the incidence of wind) or directly exposed without protection in mounting blocks. Figure S5 illustrate the performance comparison of traditional diffusion tubes and a sensor system in Manchester. The data from these diffusion tubes have been used to correct the sensor shown here and explained in detail in Section 3.6 (Figures 9b and 9c).

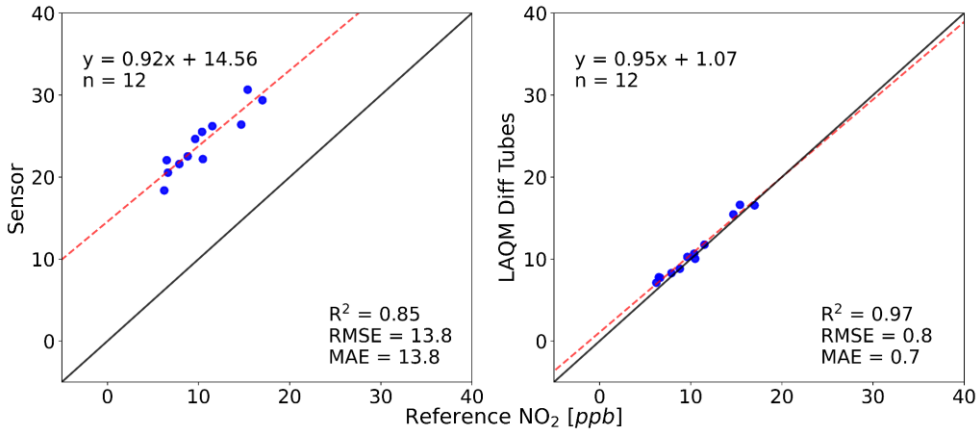

Figure S5. The left plot displays the correlation between an air quality sensor's readings and those from a reference monitor for NO_2, while the right plot demonstrates the LAQM diffusion tube performance. The LAQM plot shows a tighter correlation with the 1:1 line, indicating a higher accuracy in measuring NO_2 concentrations for the period Nov 2020 - Nov 2021 at the Manchester supersite (blue dots represent monthly averages).

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