EPA Tools & Resources Webinar:
Air Sensor Performance Testing Protocols, Metrics, and Target Values for PM2.5 and Ozone
March 24, 2021 | Responses to Questions Asked During the Webinar

Testing and Sharing of Test Results

1. How about measuring the performance of the sensors with a nanosensor that will check for extremely small molecules of pollutants? Would EPA address this topic in the upcoming SBIR?
   The testing protocols are intended for sensors that measure $PM_{2.5}$ and O_3 only. SBIR solicitations vary and funding opportunities can be found here: https://www.epa.gov/sbir.

2. Wouldn't a base testing be more useful as you're comparing in a real-world environment with real world pollutant matrix? Or is this guidance more for new or untested devices?
   Base testing (field testing) is recommended to understand how sensors perform in real-world environments with varying pollutant mixtures. Enhanced testing (laboratory testing) is recommended to evaluate sensors over a range of conditions that are difficult or challenging to test in the field. This guidance is meant for any new or existing commercially available sensor that measures $PM_{2.5}$ or O_3.

3. I hear some references to "out of box" testing. Is a calibration allowed or expected to be performed before the base or enhanced testing is started?
   Sensors evaluated should be in the same condition as they were received from the manufacturer. Testers should not modify any manufacturer calibrations or perform additional calibrations. The reasoning is that a user may not be able to perform additional calibrations or the users may find the performance of the device sufficient without additional calibrations. If additional calibrations are conducted prior to testing, the evaluation would not represent an out-of-the-box sensor. If a sensor manufacturer expects a user to calibrate the sensor on receipt, it is recommended that separate tests and testing reports be filled out – one with calibration and one without calibration.

4. Who do you anticipate would be doing the testing? Is the idea for entities with extensive laboratory facilities (like AQ-SPEC), or the device manufacturers themselves? And when will results of based/enhanced testing results be available to consumers/end-users?
   The intended audience for the reports includes sensor manufacturers, sensor developers, and testing organizations. Consumers may also wish to conduct testing, but they would need access to either testing equipment/facilities, funding to build such infrastructure or access to technical expertise. EPA recommends that testers share their results on their respective websites for consumers to view. For more information, please see the frequently asked questions page: https://www.epa.gov/air-sensor-toolbox/frequently-asked-questions-reports-air-sensor-performance-testing-protocols.

5. Where and to who do we report results to for enhanced testing?
   EPA recommends that testers share their results on their respective websites for consumers to view. Please see the frequently asked questions page for more information: https://www.epa.gov/air-sensor-toolbox/frequently-asked-questions-reports-air-sensor-performance-testing-protocols

6. Does part of the laboratory testing include the changing of concentrations without stopping the experiment?
   Yes. Sensors are tested at different pollutant concentrations for the drift test and accuracy at high concentration test. For both O_3 and $PM_{2.5}$, sensors are evaluated at a low concentration and a mid-concentration for the drift test at Day 1 and Day 60. Sensors are then tested at a higher concentration to determine accuracy at higher pollutant levels.

7. What are the key conditions for repeatability of these testing protocols?
   For base testing (field evaluation) you might not get repeatable results if the concentration range or environmental conditions are different at a test site(s). That is part of our recommendation to test in at least two different locations or at least two different seasons.

8. Do you know if these reports have been used/ or are being used by testers? We will aim to do that for our work at Texas A&M and share with you all - we tested 12 AQY1 sensors for about two years.
   We do not keep track of who has conducted the testing protocols but have heard from others who intend to use these reports. It is great to hear of your intention to use these testing protocols.

9. Is there a central testing lab that provides publicly available accuracy data for a variety of sensors?
   A number of organizations and research groups provide evaluation results for a variety of sensors. For example, evaluation results can be found on EPA's Air Sensor Toolbox webpage (https://www.epa.gov/air-sensor-toolbox), the AQ-SPEC's sensor evaluations webpage (http://www.aqmd.gov/aq-spec/evaluations), manufacturer's websites, and other trusted sources such as peer-reviewed literature.

10. Did you also consider the discussion of the European Normalization Committee of the CEN/TC264/WG42 (sensor evaluation group)? If yes, what is your point of view?
    Representatives from the CEN/TC264/WG42 participated as subject matter experts in EPA's Deliberating Air Quality Sensors Targets Workshop. These workshop discussions helped inform the development of the reports. A summary of the workshop outcomes can be found here: https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=344961&Lab=NERL. WG42 documents have not been publicly released yet.

11. For the base testing are the templates to be filled out independently for each of the two testing periods or is the data combined?
    We recommend that testers fill out separate reports for each field deployment.

12. What about testing sensors on mobile sites? (e.g., on top of a bus)
    These protocols only apply to ambient, outdoor, fixed site environments. Although not discussed in these reports, there are likely additional tests one would want to run to ensure a sensor's suitability for this application (e.g., accuracy at a variety of wind speeds, sensitivity to vibration).

13. Do these environmental chambers also collaborate with each other on the testing protocols?
    The testing protocols are entirely voluntary. Collaborations are at the discretion of the tester(s).

14. Does a long-term deployment (6 months +) of a NSIM sensor count as multiple deployments of the instrument for field testing?
    This would depend on the pollutant. If evaluating an O_3 sensor, a long-term deployment could count as multiple deployments for field testing. For O_3 base testing, we recommend that if a tester is using a single test site, one test should be conducted during the O_3 season (typically May through August) and the site should encounter a 1-hour average O_3 concentration greater than or equal to 60 ppbv for at least one day during the 30 day (or more) test period. For $PM_{2.5}$ base testing, we recommend that testing be conducted in two different U.S. Climate regions, therefore a long-term deployment at a single site would not count as multiple deployments.

15. Will the EPA audit tester's results? Can you explain the oversight role of the EPA for these reports?
    EPA does not audit tester's results or provide oversight of testing. We strongly encourage testers to be transparent about how they collect and process the data. Testers should provide information about quality control criteria used, rationale for missing or invalidated data, maintenance conducted on the instruments, and problems encountered during testing (e.g., inclement weather, power outages). This information can help consumers better understand the accuracy of the test results. Please see the frequently asked questions page for more information: https://www.epa.gov/air-sensor-toolbox/frequently-asked-questions-reports-air-sensor-performance-testing-protocols

16. Do you plan to give accreditation to testing centers?
    No, we do not anticipate providing accreditation to testing centers.

17. Will the recommended lab-based settings for $PM_{2.5}$ be harmonized with those in ASTM WK62732 "Standard Test Method for Evaluating $PM_{2.5}$ Sensors or Sensor Systems Used in Indoor Air Applications"? (e.g., this proposed method has a PM_{10} interferent).
    No. These reports apply only to sensors used in ambient, outdoor, fixed-site environments.

18. Are similar efforts being planned for other sensors, such as for methane or VOCs? Especially ones used at a distance.
    No, we are not developing similar protocols for methane and VOC sensors. We plan to develop similar protocols for only PM_{10}, NO_2, SO_2, and CO sensors.

19. $PM_{2.5}$ is also a concern for indoor environments—not only during wildfires, but also in monitoring other polluting activities (e.g., cooking, fireplace usage, etc.). To what extent can these testing protocols be applied for use in sensors indoors, as well? Are there any plans for similar work for indoor air quality sensors?
    These reports apply only to sensors used in ambient, outdoor, fixed-site environments. Other organizations evaluate air sensors in indoor environment. Some examples include the Lawrence Berkeley National Laboratory (https://indoor.lbl.gov/air-quality-sensors) and the National Institute for Occupational Safety and Health (NIOSH; https://www.cdc.gov/niosh/topics/drst/default.htm). Additionally, ASTM is currently developing test methods for evaluating the performance of indoor air quality sensors (ASTM WK62732: https://www.astm.org/DATABASE.CART/WORKITEMS/WK62732.htm).

20. The enhanced testing does not seem to have a reference method. Is that correct?
    For enhanced testing, it is recommended that EPA-designated Federal Reference Methods (FRMs) and / or Federal Equivalent Methods (FEMs) sample from the environmental chamber to verify the chamber conditions and to provide a basis of comparison with the sensor measurements.

21. Has there been any interest in having tests run by 3rd party organizations to provide unbiased evaluation?
    There are currently no third-party independent organizations that evaluate or review air sensor performance. For more information, please see the frequently asked questions page: https://www.epa.gov/air-sensor-toolbox/frequently-asked-questions-reports-air-sensor-performance-testing-protocols

22. How often do you recommend testing the sensors, after deployment?
    This depends on the study and what environmental conditions a sensor is exposed to.

23. How frequently do sensors need to be recalibrated ($PM_{2.5}$)?
    Please refer to the manufacturer's recommendations or user manual for calibration schedules. The relationship between the sensors and FRM/FEM measurements may change due to large changes in environmental conditions, particle sources, or particle composition. This changing relationship may require sensors to be "re-calibrated" to meet a project's data quality objectives.

24. Are you working on creating testing standards for particulates below $PM_{2.5}$ such as $PM_{1.0}$ or $PM_{0.5}$?
    No. We plan to develop additional testing protocols for only PM_{10}, NO_2, SO_2, and CO sensors.

25. The protocol you mention for field testing recommends three sensors. Given the PurpleAir sensor has two channels would two units suffice?
    No. We define a 'sensor' as an integrated set of hardware and software that uses one or more sensing elements to detect or measure pollutants. If a single sensor has multiple sensing elements, it is still considered one sensor.

26. Have you explored testing "ensembles" of low-cost sensors (i.e., 3 or 4 sensors averaged together) vs reference data?
    We are not exploring "ensembles" of sensors. The testing protocols are intended to evaluate 3 identical sensors having the same make, model, and firmware version.

27. How we handle the systemic bias between $PM_{2.5}$ FEM instruments (e.g., BAM vs. T640) during the sensor testing?
    This is outside of the scope of the reports. Please visit EPA's Ambient Monitoring Technology Information Center (AMTIC) webpage for detailed information about FEM instruments (https://www.epa.gov/amtic).

28. Have any companies/manufacturers provided test results of their equipment? If so, do you have information/links on the companies and their equipment?
    We do not keep track of who has conducted the testing protocols and encourage manufacturers to make test reports available on their respective websites.

29. Are there sensors that have passed your evaluation criteria, and if so, which?
    These protocols are entirely voluntary. We are not proposing a pass/fail grade. Instead we encourage testers to report all information so that consumers can make choices based on their intended application of interest. We do not keep track of test results and encourage testers to make test reports available on their respective websites.

30. Some "sensors" just use GPS to report modelled data for a particular site. Would these "sensors" pass your testing?
    We recommend that testers disclose this information in their testing reports.

31. R^2 and RMSE are strongly dependent on the concentration during collocation (especially for PM). Are there any ideas on how to take that into account?
    We acknowledge that R^2 and RMSE are dependent on the concentration levels and can be influenced by higher concentration values. We have recommended other performance metrics such as bias to help compensate for the limitations with R^2, for example. Specifically, for the $PM_{2.5}$ test protocols, under high PM events such as wildfire smoke conditions, RMSE may exceed the recommended target value. For these cases, we have provided the option of reporting the normalized RMSE (NRMSE) which should account for higher ambient $PM_{2.5}$ levels.

32. I just reviewed the Table of Contents for the fine PM report. I don't see a listing or compilation of testing results for different NSIM technologies. Will EPA be pulling together results/reporting information for the public?
    We do not keep track of who has conducted the testing protocols. We are planning to post results (using the reporting templates) from our own, independent field evaluations of sensors to EPA's Air Sensor Toolbox webpage (https://www.epa.gov/air-sensor-toolbox) in the near future.

33. Are the evaluations of the equipment used in the project available for public review? I ask because what is important in financially limited projects, which is most projects, is not wasting project funds.
    We do not keep track of who has conducted the testing protocols. We recommend that prior to purchasing a sensor, users should ask the sensor manufacturer to share performance evaluation results if their devices have been tested using EPA's or any other available testing protocol(s). You can find other performance evaluation results by visiting EPA's Air Sensor Toolbox webpage (https://www.epa.gov/air-sensor-toolbox), AQ-SPEC's sensor evaluations webpage (http://www.aqmd.gov/aq-spec/evaluations), or by searching other trusted sources such as peer-reviewed literature.

34. What is the best way to share performance metrics for our State's sensor study with EPA to help inform EPA's sensor evaluations?
    We recommend posting the testing results on your webpage. Feel free to contact us when this information is available.

35. Does EPA plan to verify any of these results? What if there is a disagreement?
    EPA does not verify the testing results. We suggest that consumers review both the visual displays and data in the testing reports to gage how the metrics compare to the recommended target values.

36. Was the baseline drift just affecting the baseline or does it also affect the span/gain?
    Both the baseline and span/gain drift can be affected.

37. What meteorological parameter have you seen affects the most or creates the greatest variability in sensor measurement for $PM_{2.5}$?
    Relative humidity (RH), ambient temperature (T), and dew point can influence $PM_{2.5}$ sensor performance. Current literature suggests that these impacts vary from sensor to sensor. T and RH can introduce positive or negative bias to sensor measurements.

38. Do you have any recommended criteria for "co-location"? (e.g., how close the sampling inlets should be between air sensors and FRM/FEM).
    Yes. For co-location at a testing site, we recommend that the air sampling inlet for the sensors are within a height of ± 1 meter vertically of the air sampling inlet of the FRM/FEM monitor. Other recommended criteria are summarized in the frequently asked questions webpage: https://www.epa.gov/air-sensor-toolbox/frequently-asked-questions-reports-air-sensor-performance-testing-protocols.

39. The common citizen cannot/will not buy and perform the testing on three sensors. Any recommendations on how to handle concerns from citizens with only one monitor?
    These reports are intended for testing organizations, sensor manufacturers, and sensor developers. Users may also be able to compare the reports for several devices when making purchasing decisions. We hope that future availability of testing reports will help the public better understand sensor performance and help them make informed purchasing decisions.

Target Values

40. Are these recommended target values specific to US? Because in India error can be very high.
    No. Target values were recommended based on sensor evaluation results from published peer-reviewed literature worldwide. Please see Appendix D (in both reports) which summarizes the studies used to inform the target values.

41. Is there not a danger with setting a target? This will not distinguish between an instrument that just passes and one that passed by a large margin.
    Not necessarily. We encourage testers to provide visual displays in the testing report on how a sensor performs on all the performance metrics relative to the targets. This will allow users to see how close or how far a sensor is from meeting the target threshold and allow them to make comparisons about the relative importance of each performance metric (which may depend on a user's application of interest). A target value can give consumers an indication of how a sensor performs and provide a benchmark to guide technology improvements.

42. What happens if the sensors do not meet these target values when collecting data?
    We are not proposing a pass/fail grade. Instead we encourage testers to report all information so that consumers can make choices based on their intended application of interest.

43. About target values (base testing), which variable is accuracy (how close is real number) related to? Is it related to linearity?
    We recommend calculating the root mean square error (RMSE) to measure accuracy. Although, there are many other ways to measure accuracy. We define accuracy as the measure of the

agreement between the pollutant concentration reported by the sensor and the reference instrument.

44. How did you come up with the recommended target values exactly?
    Target values were recommended based on sensor evaluation results from published peer-reviewed literature worldwide. Based on the literature, we used our own experience and judgment to recommend values considered to be reasonably achievable at this time and adequate for many non-regulatory supplemental and informational monitoring applications.

45. Are these target values for between collocated sensors, or between sensors and collocated FRM/FEM?
    Precision (standard deviation and coefficient of variation) is between collocated sensors. Bias, linearity, and error are between sensors and collocated FRM/FEM monitors.

46. Is there a target value to test sensor's stability (e.g., baseline drift)?
    We have not recommended a target value for drift as the rate and degree of drift has not been systematically quantified in the literature. Additionally, literature suggests that drift is highly variable, may depend on concentrations the sensor is exposed to, and may still occur even if a sensor is not being used. We plan to re-evaluate the targets in the future as we gain more information on drift tests and results, at which time a target value for drift might be recommended.

Monitors/Sensors

47. My understanding is that the EPA approved particulates monitors use a laser device that counts particles, and particle size, and then uses an unknown conversion ratio to get from size and count to mass. Is this correct?
    This is outside of the scope of the reports. Please visit EPA's Ambient Monitoring Technology Information Center (AMTIC) webpage for information about approved FRM/FEM monitors (https://www.epa.gov/amtic).

48. Are there recommended makers or models to consider for purchase? I'm not sure I have a budget for purchasing 3 makes and to test for which works best.
    We do not recommend makes/models of sensors to purchase. We hope that future availability of testing reports will help you make informed purchasing decisions.

49. How can we trust these sensors? Transparency seems to be lacking.
    This is a motivation for these reports. We encourage testers to provide their data and visual displays of their results to allow consumers the ability to trace data from the tests to the results. We also encourage testers to be transparent about how they collect and process the data and to report any problems encountered during the testing.

50. So, does this mean that data we receive over time will not show a jump? If so, it seems like we should not be using a sensor until it has testing data. Correct?
    Sensor performance can change for a variety of reasons at any time. It is recommended that before purchasing a device, a potential user check if the device has been evaluated in the field or laboratory environment. This could be determined by asking a manufacturer to share evaluation results, reviewing sensor evaluation results on EPA's Air Sensor Toolbox webpage

(https://www.epa.gov/air-sensor-toolbox), reviewing AQ-SPEC's sensor evaluations (http://www.aqmd.gov/aq-spec/evaluations), or by searching other trusted sources such as peer-reviewed literature.

51. When do you anticipate good quality VOC sensors being available?
    These reports do not apply to VOC sensors. We are not able to predict how VOC sensors will evolve in the future.

52. Do you expect particulate matter sensors to be as affected by humidity or air pressure as some ozone sensors are?
    Sensor evaluations have shown that particulate matter sensors can be impacted by relative humidity.

53. Many of these low-cost sensors appear to be difficult to calibrate and are disposable. Do you have any guidance for determining the end of life for field deployment?
    Please refer to the manufacturer's recommendations or user manual for the expected lifetime of a sensor.

54. What's the cost for the O_3 sensors?
    The cost of O_3 sensors varies depending on the measurement principle used and the features of a given device.

55. What is the average shelf-life for the sensors? Do they start degrading even if they are on the shelf and awaiting to be deployed?
    Please refer to the manufacturer's recommendations or user manual for the expected shelf-life of a sensor.

56. Can EPA assist/give/loan foreigners sensors/wearable for research activities?
    A list of EPA grant opportunities can be found here: https://www.epa.gov/grants. EPA has established a select number of air sensor loan programs through collaborations with various groups (https://www.epa.gov/air-sensor-toolbox/air-sensor-loan-programs) however, these programs are only available in the United States.

57. What brands and models of particulate monitors did you evaluate?
    EPA independently conducts evaluations for select commercially available sensors. Results can be found on the Air Sensor Toolbox website: https://www.epa.gov/air-sensor-toolbox/evaluation-emerging-air-sensor-performance.

58. Which brands have the best performance for, say, $PM_{2.5}$? What are their accuracies?
    Performance evaluation results can be obtained by asking a manufacturer to share evaluation results, reviewing sensor evaluation results on EPA's Air Sensor Toolbox webpage (https://www.epa.gov/air-sensor-toolbox), reviewing AQ-SPEC sensor evaluations (http://www.aqmd.gov/aq-spec/evaluations), or by searching other trusted sources such as peer-reviewed literature.

59. Do all sensors use WiFi telemetry, or are there user options for retrieving data especially when deploying more than one type of sensor at a site (e.g., O_3 & PM)?
    Currently available sensors use a variety of ways to transmit and retrieve data (e.g., local download, WiFi, cellular). These features are determined by the manufacturer.

60. Do the PM monitors evaluated use the same method, for example laser light scattering, as official PM monitors?
    FRM/FEM monitors and PM sensors use a variety of measurement methods. Common methods for PM sensors include optical particle counters and nephelometers.

Templates

61. Is there an excel template for data documentation and presentation?
    We have provided a PowerPoint template for data documentation and presentation.

62. For the sake of generating plots on the PPT template, is it recommended that testers use the collocation macro analysis tool? If so, is there an upcoming webinar on using that tool?
    Testers can use any plotting software or tools they prefer including EPA's collocation macro tool. An instructional guide on the macro analysis tool can be found here: https://www.epa.gov/air-research/instruction-guide-and-macro-analysis-tool-evaluating-low-cost-air-sensors-collocation. There are no webinars planned for using this tool.

Recommendations/Guidance

63. Does EPA have guidance for members of the public who may want to use these types of sensors to assess the air quality in a particular neighborhood or for evaluating the impact of a specific facility on members of the public in a given neighborhood?
    EPA's Air Sensor Toolbox webpage (https://www.epa.gov/air-sensor-toolbox) provides general and more technical information on sensors for a wide range of groups including the public. EPA's 2014 Air Sensor Guidebook may also be useful as you are considering use of sensors for collecting air quality measurements (https://www.epa.gov/air-sensor-toolbox/how-use-air-sensors-air-sensor-guidebook). Additionally, see EPA's handout on "Six Questions to Consider Before Purchasing Air Sensor Technology": https://www.epa.gov/air-sensor-toolbox/selecting-lower-cost-air-sensor-monitors

64. Could EPA make certain recommendations about some key parameters for reliable data (i.e., passive or forced sampling, type of sensors, parameter range, etc?)
    We recommend criteria for selecting test sites with goal pollutant concentrations to ensure that sensors are tested under a range of concentration levels. The testing protocols are not specific to any particular sensor technology or sensor device. Sensors will likely be evaluated in different environments with different pollution concentrations, pollutant mixtures, and meteorology.

65. Citizen often only see numbers, especially when they are high, and do not understand that those high numbers may be the result of poor-quality sensors being used or severe protocol or operational errors. Any advice on how to deal with this when confronted by members of the public who demand action from state regulators to address those high values, especially since states are strapped for resources to help on the front end or to sort out issues on the back end?

If a sensor device has been evaluated using these protocols, we recommend sharing the testing reports with the public. In the testing reports, we encourage testers to show plots and data of the results. Having visual displays and data to accompany an explanation of poor performance is often useful as will demonstrating how well a sensor performs on all the metrics relative to the targets. Users will be able to see how close a sensor is to the targets and how well air quality trends are captured.

Applications of Reports

66. As a potential consumer, would the most appropriate usage of the report findings be for me to compare the EPA proposed targets (for the various parameters) and the device manufacturer's stated performance values?
    Yes. Users may also be able to compare the reports for several devices when making purchasing decisions. We hope that consumers will be able to review both the visual displays and data in the testing reports and easily gage how the metrics compare to the recommended target values. We hope this information can help consumers make more informed decisions on which sensor to purchase for an application of interest.

67. Is it a concern that sensors data may be used for compliance with permits?
    The protocols only apply to non-regulatory supplemental and informational monitoring applications. Sensor data could potentially be used to inform the need for further monitoring activities, using approved regulatory instruments, for compliance related concerns.

68. Could you comment on the prospects for using air sensor data for epidemiological studies?
    There are many different ways sensors might be used for epidemiological (epi) studies. As an example, sensor data at an ambient fixed site could be integrated into epi models or be used in models to fill in data gaps in locations where regulatory monitors are sparse. Another possible use of air sensor data is for understanding health effects of wildfire smoke exposures. With the increase prevalence of wildfires and the need to obtain air quality measurements to understand potential health impacts on nearby populations, sensor technologies can offer a solution to fill this monitoring need. These sensor data could be used alone in epi studies or be fused with other data streams (e.g., regulatory monitors, satellite data) or modeling tools to provide information on health effects from exposure to wildfire smoke.

Other

69. How do you consider inaccuracies in the reference analyzers? Is there data comparing different reference instruments?
    Assessments of ambient network FRM/FEM monitors can be found here: https://www.epa.gov/amtic/amtic-ambient-air-monitoring-assessments

70. Where can we find EPA developed correction factors for adjusting PM sensor measurements for comparison with measurements by reference methods?
    Information about EPA's work on developing correction factors can be found here: https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=350075&Lab=CEMM. Also, the Air Sensor Toolbox webpage provides current information on EPA's sensor research projects: https://www.epa.gov/air-sensor-toolbox. Note that data correction equations will be

specific to the make and model of sensor and locally derived corrections may provide the most accurate results.

71. Is it possible to address sensor drift using any (statistical/analytical) methods that do not rely on comparison to reference monitors (as this sometimes is not available) in the field)?
    This is an active area of research. Most methodologies rely either on comparison to a reference monitor or known pollutant behavior. This topic is beyond the scope of these reports.

72. Is there a historical precedent of technology advancing to improve in great ways without a mandatory order or financial incentive? The presentation really hit home all the issues we currently have with lack of testing locations, air quality trends, need for consistent performance testing protocols, etc.
    This is occuring now in sensor development and manufacturing which is a highly competitive market from very small start-up companies to very large, established companies. The increased interest among the public in obtaining neighborhood air quality measurements and engaging in community science activities, has fueled the widespread use of sensors. Certain features may appeal to consumers for example cost, size, accuracy, general ease of operation, quick access to data, etc. Devices that can reliably meet the needs of consumers, can often gain traction quickly. Sensors that perform reasonably well are adopted quickly and gain popularity. This alone can be a motivation for manufacturers to improve sensors technologies and establish a leadership role in this area. Based on the early workshop that informed the reports, manufacturers expressed support for performance targets in helping identify well-performing devices from poor-performing devices.

73. What role does the traditional data quality objectives process play in these evaluations?
    The data quality objective process plays an important role in these evaluations. Where feasible, we have adapted the process used for evaluation of regulatory air monitoring instruments. We have clearly defined the goals of these reports and application space, identified what information should be provided about the devices, identified what data should be collected and timeframes, clearly defined how the tests should be conducted, defined the performance metrics and how to calculate them, and defined testable performance metrics (targets) to indicate how sensors perform.

74. Have you ever looked at "out-of-the-box" performance of reference grade instruments? Without calibration, even expensive instruments may not perform at these levels.
    Air monitoring instruments used for compliance purposes, must meet the applicable requirements in the Code of Federal Regulations (CFR) - Part of Title 40, Protection of Environment or other state environmental regulations (see, e.g., 40 CFR Parts 50, 53, and 58). Technical requirements include detailed sampling, siting, maintenance, and quality assurance requirements. Please visit the Ambient Monitoring Technology Information Center (AMTIC) for additional information: https://www.epa.gov/amtic.

75. Have you looked at the variation between PM FEM methods?
    Assessments of ambient network FRM/FEM monitors can be found here: https://www.epa.gov/amtic/amtic-ambient-air-monitoring-assessments

76. Do you know if AQ-SPEC has already agreed to adopt the approach outlined in these reports?
    Please contact AQ-SPEC directly for information on their sensor evaluation approaches.