AB 617 Recommended Source Attribution Technical Approaches

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Prepared by

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1. Overview

The results of source attribution are important for informing community emissions reduction programs, which focus on developing and implementing strategies to reduce emission impacts from specific sources contributing to a community's air quality burden. This document describes source attribution technical approaches recommended by the California Air Resource Board (CARB) to meet the following AB 617 statutory requirements:

> *California Health and Safety Code § 44391.2 (b) (2) directs CARB to provide "[a] methodology for assessing and identifying the contributing sources or categories of sources, including, but not limited to, stationary and mobile sources, and an estimate of their relative contribution to elevated exposure to air pollution in impacted communities…"*

While the Community Air Protection Program Blueprint lays out the general methodology, this document lays out CARB's five recommended source attribution technical approaches that air districts may apply. Each recommended technical approach is summarized in Table 1 and explained in more detail in Appendix A. Technical references are provided in Appendix B. CARB recognizes that, in addition to the five recommended technical approaches, new technical approaches appropriate for application in communities may evolve over time. With this in mind, Appendix C provides requirements for the development or application of new or equivalent source attribution technical approaches that might evolve over time and that are technically equivalently to one or more of the five CARB-recommended technical approaches provided in this document.

2. Planning for Source Attribution

Given the condensed schedules associated with the AB 617 program, it is recommended that source attribution needs (i.e., selection of technical approaches and identification or collection of requisite input data) be considered early on in the planning process for either community air quality monitoring plans or community emission reduction programs. Air districts have one year to adopt a community emissions reduction program from the date a community is selected by the CARB Governing Board. Similarly, community air monitoring plans must be implemented within one year of a community being selected, except for the first year communities that have slightly less time for a monitoring plan implementation. During the monitoring plan development, air districts, working with communities, will determine specific monitoring needs, site planning, and instrumentation for deployment. Given that data collection efforts can take a significant amount of time, consideration of source attribution data input needs during these planning phases is highly recommended.

Table 1. Summary of Source Attribution Technical Approaches (Details in Appendix A)

Technical Approach	Description	Community Inventory	Regional Inventory	Met Data	Air Quality Monitoring Data	Source Test Profiles[1]	Source Signatues[2]	Speciated Data[3]	Advantages	Limitations
Community Inventory Ratios	Calculating and comparing ratios of source-specific emissions or comparable activity data inside and external to a community.	x							Uses only the inventory data. Minimal data collection.	No air quality monitoring or meteorological data included.
Community-Specific Air Quality Modeling	Sensitivity simulations to estimate the impact and contributions of emission sources or categories in a community.	x	x	x		x			Estimates the effects of new control measures. Can use multiple meteorology years.	No air quality monitoring data included. Detailed inventory required.
Targeted Air Monitoring/Back Trajectory/ Pollution Roses/ Inverse Modeling	Combining emissions, air quality monitoring, and meteorology (e.g., prevailing wind speed and direction) data to describe the sources affecting air quality at the monitoring locations.	x		x	x			x (Inverse Modeling only)	Flexible in terms of number of sampling locations and analysis. May be able to be performed on mobile platforms and low cost platforms depending on data quality need. Can use multiple meteorology years. Inverse modeling can quantitatively assess the agreement between emission inventory and monitored data.	May provide limited results based on available analysis and number of samples. Monitor locations require careful selection. Highly dependent on the resolution of the input data. Inverse modeling can be computationally expensive by involving both air quality/dispersion modeling and statistical calculations
Chemical Mass Balance	Utilize detailed chemically speciated air quality monitoring data to attribute emissions burden based on source test measurements of chemical species from emission sources.	x		x	x	x		x	Few air monitoring locations required. Results complimentary to PMF. May identify specific sources depending on source profiles.	Requires complete and representative source profiles. Assumes profiles represent emission sources. Cannot identify unknown sources.
Positive Matrix Factorization (PMF)	Multivariate factor analysis used to determine factor profiles and contributions composed of species identified from the same sources.				x		x	x	Can be used as a complimentary source attribution strategy with CMB. Does not require detailed community inventory. Can be used to identify sources that may not be in the inventory.	Requires large number of samples. More difficult to link observed factors to sources. Requires expert knowledge about the details of various source profiles.

1 - Source profiles are the mass abundance (fraction of total mass) of a chemical species in source emissions. Source profiles are intended to represent a category of source rather than individual sources.

2 - Source signatures are the unique chemical signatures of a source that are expected to be detected at a receptor location.

3 - Speciated data contains the chemical composition of an air sample/source profile or emissions to trace back to its source. The speciated data can include analysis of ions, trace elements, metals sulfate, nitrate, sodium, potassium, ammonium, and carbonaceous constituents.

Appendix A
Description of Individual Source Attribution Technical Approaches

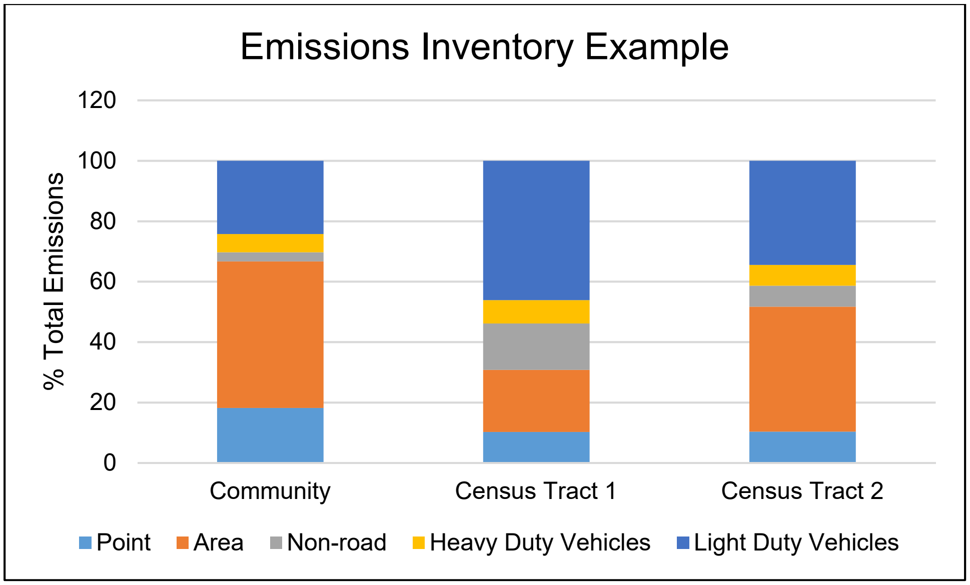
1. Community Inventory Ratios

Producing representative community inventory ratios requires the availability of a detailed community-level inventory for each community. The community-level inventory shall consist of the mobile, area-wide, and stationary sources resolved down to a geographic location within and surrounding the community. Generally, the community-level inventory shall consist of transitioning area-wide sources that significantly contribute to the community air pollution burden to distinct stationary sources having explicit geographic coordinates and source-specific emission characteristics. Similarly, mobile sources contributing significantly to the burden shall have their activity and emission characteristics refined to adequately characterize community-level emissions. Below is a summary of the basic needs and outputs of this method. Note that emission inventory should be developed for criteria air pollutants (e.g., PM2.5, NOx, etc.) and toxic air contaminants (DPM, individual heavy metals and toxic VOCs) specifically.

Community Inventory Data Inputs and Supporting Data	Community Inventory Data Processing	Community Inventory Source Attribution Results
• Detailed road and traffic network within and surrounding the community. • Stationary source locations and source characterization. • Area-wide source geographic location(s) and source-specific emission characteristics to represent as a stationary source. • Refined area-wide sources spatial surrogates.	• Converting area-wide sources to appropriate point sources and applying spatial surrogates. • Estimating mobile source emission from network data, fleet characteristics, temporal factors, and emission factors.	• Each source and class of sources is linked to their overall emissions and the relative contribution of overall emissions impacting the community.

Figure 1 provides an example break down. In this example, the percentage of overall emissions each source contributes to the air pollution impacting each city is shown via a bar graph. This break down could be extended into further categories as data allows.

Figure 1. Example of Emission Inventory Ratio Result



For illustrative purpose only.

2. Community-Specific Air Quality Modeling

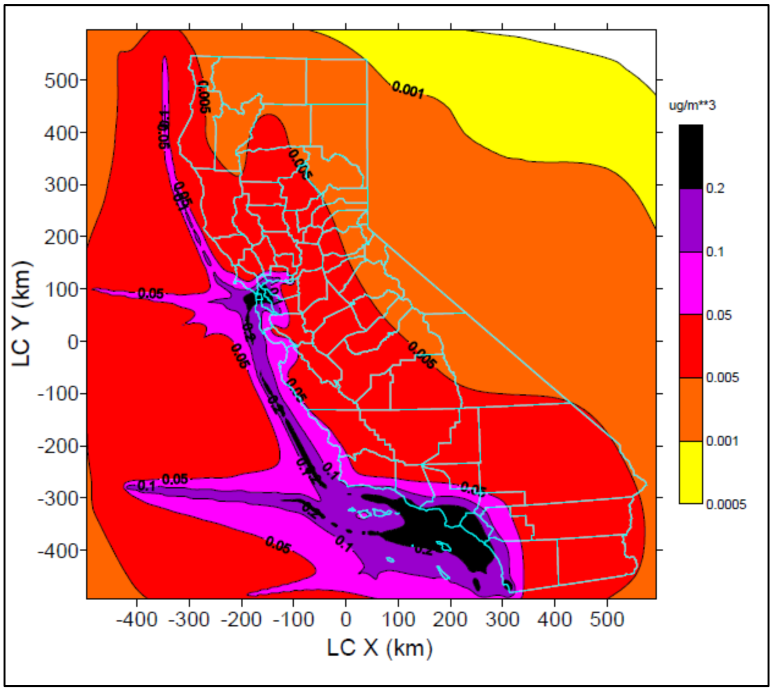
Community-specific air quality modeling uses the location and emissions data from the detailed community inventory and meteorological data to estimate the contribution to overall air pollution burden from each source or source category in the inventory.

A variety of dispersion and photochemical models are available to perform community-specific air quality modeling. Additionally, results from air quality modeling sensitivity runs may be used to facilitate cost-effectiveness calculations for potential emission reduction measures prior to their inclusion into a community emissions reduction program.

Community-Specific Air Quality Monitoring Data Inputs and Supporting Data	Community-Specific Input Data Processing	Community-Specific Air Quality Modeling Results
• Detailed community scale inventory, including estimate emissions from mobile, area-wide, and point sources. • An existing regional air quality modeling system that meets acceptable model performance benchmarks. • Meteorological and geographic data.	• Data inputs formatted into applicable format for dispersion (CALPUFF, AERMOD) and photochemical modeling system (e.g., CAMx, CMAQ). • Running air quality model on computers with adequate processing power and storage space.	• Relative contribution of emissions and risk by emission sources (mobile, area-wide, and stationary sources).

Figure 2 provides an example visualization of air quality modeling results. In this example, the spatial pattern of a pollutant over a certain time period from air quality modeling is shown in the form of colored concentration contour, with a base map overplayed. Air quality modeling can be configured to estimate how much particular sources impact a community by predicting the concentrations in this community resulting from dispersion of emissions from individual sources that may be within or surrounding the community.

Figure 2. Example of Air Quality Modeling Results[1]



[1] For illustrative purpose only. Source: https://www.arb.ca.gov/regact/2008/fuelogv08/appe1fuel.pdf

3. Targeted Air Monitoring, Back Trajectory, Pollution Roses and Inverse Modeling

Targeted air monitoring, back trajectory, and pollution roses can be used to support source attribution by linking observed monitoring data back to a specific source. Targeted monitoring, like an instrumented mobile monitoring vehicle for fence-line monitoring, could be used to estimate direct or relative levels back to a specific emission source. This can be useful when implementing source attribution in a phased approach, where initial screening and assessment (Phase 1a) can take place using mobile and low cost monitoring, which can then be used to inform site planning of fixed monitor deployment locations or other data collection needs for more exhaustive source attribution under Phase 2.

Back trajectory and pollution roses combine air monitoring data with meteorological data to locate potential sources that might impact location(s) where the monitoring data was collected. This approach is limited by the resolution of the meteorology data and its focus on the specific location where the monitoring data was collected. Back trajectory simulates the movement of air particles back from the monitoring site to their likely emission source(s), utilizing potential meteorological streamlines or pathways that plume of emissions might follow to impact the monitoring location. Pollution roses captures the prevailing wind directions during sampling, indicating which direction the sources affecting the site are likely located.

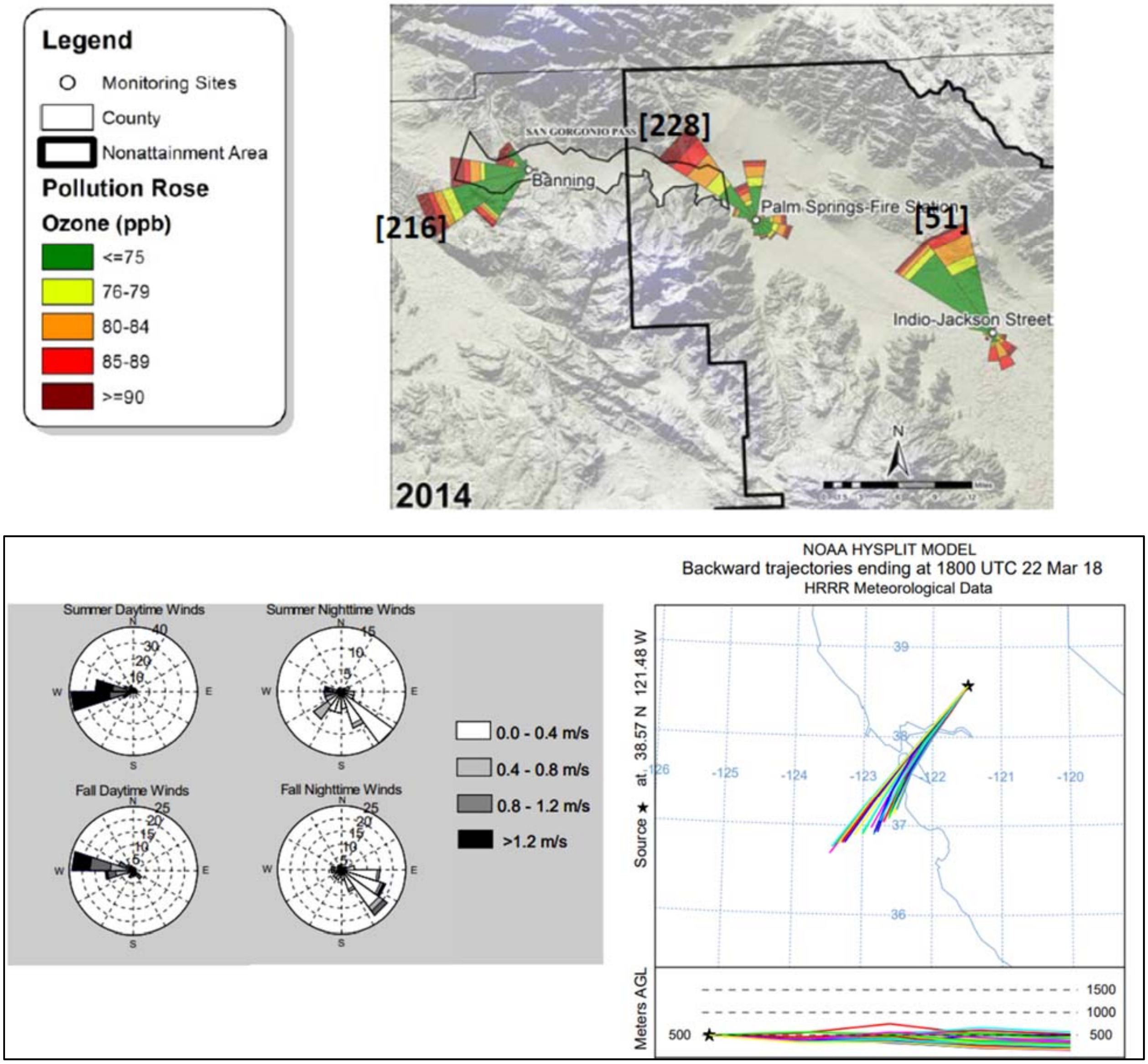
Inverse modelling refers to a class of statistical methods to validate emissions inventory using monitored concentrations and modeled source-receptor relationships. Air quality modeling as a source-oriented approach can predict concentrations at monitoring sites from different sources using emissions inventory, but additional analysis may be required to understand the difference between modeled and measured concentrations. On the other hand, receptor models such as CMB and PMF do not account for dispersion and chemistry on the pathways from sources to monitoring sites, therefore additional analysis is needed when using their results to validate emission inventory. Inverse modeling draws from a similar foundation to back trajectory analysis and combines statistical inference with traditional dispersion modelling to bridge these gaps. It also can be optimized using inference algorithms in the machine learning literature to suit the needs of community-scale air quality applications which typically requires extensive data processing and analytical computing resources.

Additional guidance on conducting targeting air monitoring, pollution rose, back trajectory and inverse modeling analyses can be from the Online Resource Center, TraPSA, NOAA's HySplit Model, WRF-STILT, and/or FLEXPART-WRF and a relevant article (https://doi.org/10.5194/acp-13-3661-2013) on inverse modeling by Brioude et al.

Data Inputs and Supporting Data	Data Processing	Results
• Detailed community scale inventory, including estimate emissions from mobile, area-wide, and point sources. • Meteorological and geographic data. • A detailed monitoring plan that includes at least one week for each season of monitoring data for chemical species relevant to the community as determined by the community inventory.	• Processing and performing quality assurance on monitoring data. • Ensure selected model has undergone model performance evaluations. • Formatting monitoring data results for selected model. • Executing selected model and interpreting results.	• For each sampling location, a pollution rose showing pollution distribution and concentration relative to sampling location. • For back trajectory, map showing likely trajectory of molecule back from sampling location. • Updated emission estimates (and uncertainties) for different source types that optimizes the agreement between monitoring data and emission inventory. (Inverse monitoring) • Source apportionment of concentrations at monitoring sites using original and updated emission inventory estimates. (Inverse monitoring)

Figure 3 provides an example pollution rose and a back trajectory. In this example, the wind rose shows the direction and magnitude of air pollution at various times along with the meteorological conditions, which can be used to estimate the sources impacting the monitoring location. The back trajectory example shows the possible origins of a molecule of pollution by estimating its path to the air monitoring, taking into to account local meteorology. The graph below the map shows the height of the pollutant as it travels.

Figure 3. Example of a Pollution Rose and a Back Trajectory[2]



[2] For illustrative purpose only. Wind rose image source: https://www.arb.ca.gov/planning/sip/planarea/scabsip/AppC_CoaO3WOE.pdf.
NOAA HYSPLIT model READY webpage: http://www.ready.noaa.gov.

4. Chemical Mass Balance

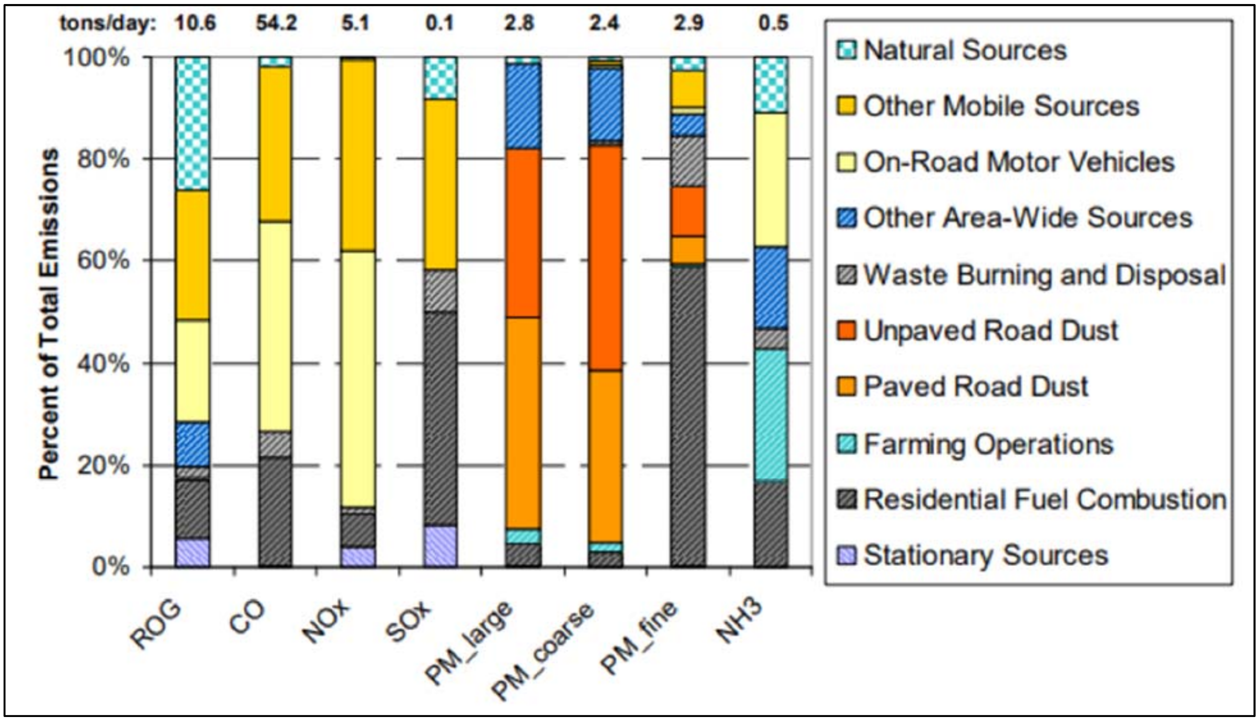
A CMB model can be used to estimate the source contribution of air pollutants measured at a receptor site using speciated profiles of potentially contributing sources and the corresponding ambient data from analyzed samples. A CMB model assumes that the individual air pollutants measured at a receptor is the sum of the contributions from all the sources within its vicinity. It is important to note that the chemical signatures of each specific source emissions, i.e. source profiles or "fingerprints" impacting a receptor are required to use CMB models. CMB models also do not account for chemical and physical processes in the atmosphere that lead to transformation or removal of air pollutants. Therefore, some level of expertise is required to ensure proper assessment of the CMB output. CMB and PMF are complementary modeling strategies to apportion the primary source contributions to air pollutants measured at a receptor site.

Additional guidance on CMB can be found from EPA's website. Sampling guidance should follow AB 617 community air monitoring Guidance.

CMB Data Inputs and Supporting Data	CMB Data Processing	CMB Results
• Detailed community scale inventory, including estimate emissions from mobile, area-wide, and point sources. • Detailed meteorological and geographic data. • Detailed monitoring plan that includes specifies the minimum number of air monitoring locations and the minimum sampling period for air monitoring data to be collected to support CMB. • Detailed emission profiles. i.e., chemical signatures. • The receptor concentrations, with appropriate uncertainty estimates. • Receptor analysis including wind direction/trajectory and upwind/downwind measurement.	• Processing and performing quality assurance on monitoring data. • Formatting monitoring data results for CMB model. • Executing CMB model and interpreting results.	• For each sampling location, a breakdown of source contributions to ambient air pollution levels.

Figure 4 provides an example breakdown. In this example, the relative contribution of each source to the overall emissions is displayed in the bar graph, clearly identifying the major sources of each pollutant.

Figure 4. Example Chemical Mass Balance Analysis[3]



[3] For illustrative purpose only. Source: https://www.arb.ca.gov/research/ltads/final/ch7.pdf

5. Positive Matrix Factorization

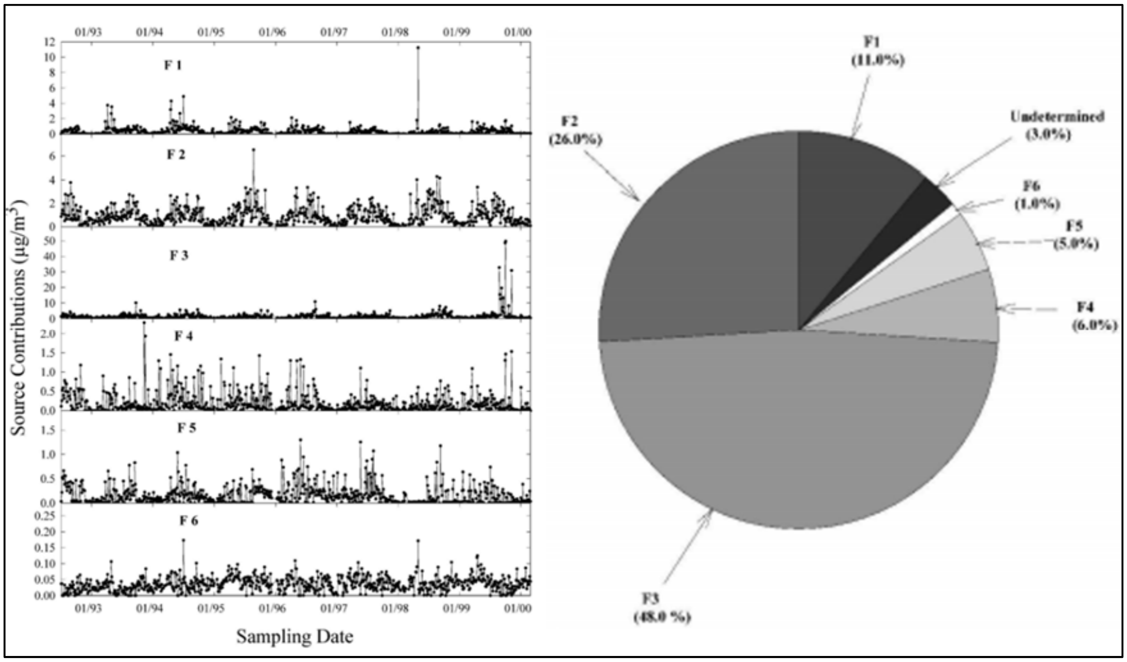
A PMF model can be used to estimate the source contribution of air pollutants measured at a receptor site. PMF mathematically deconstructs the matrix of air pollutant concentrations measured at a receptor site to resolve "factors" that are associated to unique chemical signatures and time series. These factors describe the characteristics of potential sources that contributed to the air pollutants measured at a receptor location. PMF may not be able to identify a specific emission source (e.g., emissions from specific vehicles on a road that did not pass smog check), but instead it is able to effectively identify source categories (e.g., gasoline vehicles, diesel vehicles, etc.) Source categories are identified based on expert interpretation of the resolved factors. Depending on the similarities in source emission patterns, chemical speciation, and measurement/modeling uncertainties, smaller or less dominant chemical species can be erroneously attributed to a factor, therefore expert assessment and proper caveating of the PMF output is necessary.

Additional guidance on PMF can be found from EPA's website. Sampling guidance should follow AB 617 community air monitoring guidance.

PMF Data Inputs and Supporting Data	PMF Data Processing	PMF Modeling Results
• Detail speciation data, including toxic and tracer compounds, for the emissions of each source type. • Uncertainty estimates for all air pollutants of interest.	• Processing and performing quality assurance on monitoring data • Formatting monitoring data for PMF model. • Executing PMF model and interpreting results. • Evaluating the results using supplemental information (e.g., local scale inventory, meteorological data, PMF results, back trajectory results, receptor analysis including wind direction/trajectory and upwind/downwind measurement, etc.)	• For each sampling location, a breakdown of source contributions to ambient air pollution levels.

Figure 5 provides an example breakdown. In this example, the source profile attributed to six factors, F1 – F6, are shown along with their relative contribution to ambient air pollution. Each of these factors would then be associated with an emission source category.

Figure 5. Example Positive Matrix Factorization Analysis[4]



[4] For illustrative purpose only. Source: https://www.arb.ca.gov/research/apr/past/01-348.pdf

Appendix B
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a. Methods and Approaches

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Appendix C
Guidance on Developing or Justifying New Technical Approaches

1. New Technical Approaches

The technical approaches presented in Appendix A are well-established for performing source attribution and are being widely used as cited in the literature (Appendix B). CARB strongly recommends using one or more of these methodologies for source attribution.

Over time, as new approaches are developed or evolve, CARB, the air districts, and communities should evaluate these new approaches and employ the best available practices and enhanced methods to perform community-scale source attribution. As part of the process for considering and choosing new methodologies, they should be justified as capable of providing accurate and representative results to meet AB 617 program requirements (§44391.2(b)(2)) based on appropriately rigorous scientific review.

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