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Ada E MÃ¡rquez Comments - CEQA Comment Letter Appendix A Ref (1 of 8)

Additional submitted attachment is included below.

BAY AREA AIR QUALITY MANAGEMENT DISTRICT

January 2020

Permitted Stationary Source Risk and Hazards Screening Tool Methodology

Stationary sources of air pollution—including complex sources such as metal smelting, wastewater treatment plants, and refineries as well as smaller facilities such as diesel generators, gasoline dispensing facilities (GDFs or gas stations), and boilers—are regulated and subject to permit conditions established by the District. The District maintains a database of its permitted sources and their associated emissions. These emissions are determined either through direct measurement via source test or by engineering calculation based on process throughput and industry emission factors. Emissions from all permitted facilities are reported annually to the California Air Resources Board (CARB) under the California Emissions Inventory Development and Reporting System (CEIDARS, CARB 2013[1]) and, subsequently, reported to US Environmental Protection Agency (EPA) to supplement the National Emissions Inventory database (NEI, EPA 2014[2]).

The CEIDARS report formed the basis of the permitted source inventory for the CEQA risk and hazards screening tool. The inventory focused on fine particulate matter less than 2.5 microns in diameter (PM2.5) and toxic air contaminants (TACs) including diesel particulate matter (DPM). DPM is used as a surrogate to represent all carcinogenic compounds associated with the combustion of diesel fuel used by standby generators and fire pumps. Individual toxic compounds were included in the analysis if the generator used other types of fuel such as natural gas.

The current report differed from previous version by including GDFs in the point-source inventory. Historically, emissions from GDFs have been aggregated and reported as part of county-level area totals in CEIDARS. The current database includes over 2,265 retail and nonretail GDFs geolocated with actual or permitted throughputs used to estimate their emissions.

Using emissions data specific to each stationary source, the Air District developed the CEQA risk and hazards screening tool that estimates screening level cancer risks, chronic hazard index, and fine PM concentrations at the centroid of the facility. The screening level cancer risks and fine PM concentrations are estimated to be intentionally conservative and are based upon worst-case assumptions.

The screening tool contains the following information:

- Unique plant number assigned by the District. Most plant numbers greater than 100,000 represent retail and non-retail gasoline dispensing facilities;
- Plant name and address;
- Centroid location of the plant based on UTM NAD83 Zone 10 datum; PlantNumber_SourceNumber combination denote the location of the backup generator as provided based on responses to an Air District survey by the facility representative;
- Chronic cancer risk (in millions) and hazard indices for the combined emissions associated with each plant based on conservative assumptions; and
- Conservatively estimated PM2.5 concentrations in units of micrograms per cubic meters.

[1] CEIDARS 2.5 Database Structure can be found at https://www.arb.ca.gov/ei/drei/maintain/dbstruct.htm
[2] EPA NEI web page can be found at: https://www.epa.gov/air-emissions-inventories

The screening level risks and hazards were estimated by multiplying the CEIDARS emissions with conservative exposure assumptions. For permitted sources (excluding gasoline dispensing facilities (GDFs)) , a cavity effects screening procedure was used to model aerodynamic downwash from nearby buildings for worst case one-hour ambient air concentrations. The methodology conservatively estimates the buildup of pollution at a receptor located immediately adjacent to the lee side of the building, depicting worst case dispersion. From EPA's Screening Procedures for Estimating the Air Quality Impact of Stationary Sources (1992), the cavity equation is as follows:

Air Concentration (1 hour maximum) = Q / (1.5 x A x u)

Where:

Concentration	=	One hour maximum exposure concentration at the fenceline of the plant (ug/m3);
Q	=	Emission rate (g/sec);
A	=	Cross section area of the building normal to the wind (m2); and
U	=	Wind speed (m/sec).

Building cross section was assumed to be 25 feet high by 40 feet wide, approximately 92.7 square meters. Calm winds of two meters per second, taken from EPA's screening modeling guidelines, was used. The maximum one-hour concentration, estimated by applying these factors, was then multiplied by 0.1 to convert the one-hour concentration to an annual average concentration, for estimating risks and hazards.

A different modeling methodology was used to handle emissions from gasoline dispensing facilities to handle the complex dispersions associated with losses from spills, pipe vents, and pumps. EPA's AERMOD atmospheric dispersion model was used to develop worst-case ground-level annual concentrations. AERMOD compatible meteorological files were processed for representative Bay Area cities including Concord, Hunters Point in San Francisco, Oakland Airport, Petaluma Airport, UC Richmond Campus, and San Jose Airport using AERMET. Over two dozen different building configurations were modeled to quantify building downwash effects. GDF emissions were apportioned by assigning a majority of the losses (92.7%) to dispensers and a small fraction (7.3%) to vents. Given that most gas stations have similar sized vents from their underground tanks, storage tank vents were consistently modeled as point sources of 10 feet height and two-inch diameter; exhaust gas velocity of 0.00035 meters per second and exhaust temperature of 294 degrees Kelvin. Six dispenser were modeled in each run and refueling and spillage were modeled as volume sources with an initial lateral dimension of 2.3 feet.

For each building configuration and meteorological data set, the annual average atmospheric dispersion factor (also known as Chi/Q) was estimated using AERMOD. The Chi/Q factor, the ratio of the pollutant ground level concentration (Chi) to the source emission (Q) at specified distances and directions from the source, describes the dilution and dispersal effects caused by the atmosphere once the pollutant is released. GDF ground-level concentrations were estimated by multiplying the chemical-specific emissions by the area-specific Chi/Q using the most conservative building configuration. County-specific Chi/Q are presented in Table 1.

Table 1: Area-specific Chi/Q for GDFs

County	Chi/Q (ug/m3 per gram/sec)
Alameda	3782
Contra Costa	5287
Solano	6236
Marin	6236
Napa	6236
Santa Clara	3420
San Francisco	4585
San Mateo	6236
Sonoma	6236

In most cases, emission data were taken from the CEIDARS report. Operators report their facility emissions annually or bi-annually depending on their permit cycle. Unlike most stationary sources, GDF emissions are reported to CARB as county-wide estimates rather than on an individual facility-basis. To quantify emissions per gas station, the Air District used reported annual throughputs conducted during facility inspections. If inspection throughputs were unavailable, permit throughputs were used. Individual chemical emissions for gas station specific compounds (i.e, benzene, toluene, ethylbenzene, naphthalene, xylenes, and hexane) were estimated by multiplying the station throughput by CARB emission factors.

Cancer risks were estimated by multiplying the Chi/Q, chemical-specific emissions, exposure factors, and chemical toxicity factors for each station. Cancer risk is the incremental probability that an individual will develop cancer over a lifetime as a direct result of exposure to potential carcinogens from anthropogenic sources. The estimated risk is a unitless probability, often expressed as the number of people who might experience cancer per million people similarly exposed.

The cancer risk methodology follows guidelines from Cal/EPA's Office of Environmental Health Hazard Assessment (OEHHA) and the risk management guidance for stationary sources adopted by the California Air Resources Board (CARB) and the California Air Pollution Control Officers Association (CAPCOA). Cancer risks were calculated over an assumed 70-year lifetime by multiplying the annual average chemical concentrations by the chemical intakes and the chemical-specific potency factors (CPFs). The chemical concentrations were modeled, in most cases, from the point of release to the exposure point at the downwind residential locations. Contributions from all individual sources were then summed by facility for cancer risks. The chemical intake or dose describes the frequency and duration of the exposure, estimated using the breathing rates, exposure durations, and exposure frequencies. In accordance with OEHHA's revised health risk assessment guidelines[3], the intake methodology was updated to address children's greater sensitivity and health impacts from early exposure to carcinogenic compounds. The updated calculation procedures include the use of age-specific weighting factors, breathing rates, fraction of time at home, and reduced exposure durations. Each factor is described below:

- Age Sensitivity Factor (ASFs) account for the heighted sensitivity of children to carcinogens during fetal development and early childhood. Consistent with OEHHA, the Air District uses a factor of 10 for exposures that occur from the third trimester of pregnancy to two years of age, three for exposures that occur from two years through 15 years of age, and one for all other age groups. The Air District has been incorporating ASFs in its air permits since 2010.

[3] OEHHA, 2015. Air Toxics Hot Spots Program Guidance Manual for the Preparation of Health Risk Assessments 2015. Available at: http://oehha.ca.gov/air/crnr/notice-adoption-air-toxics-hot-spots-program-guidance-manual-preparation-health-risk-0

- Daily Breathing Rates (DBR) is the age-specific daily air intake. OEHHA developed a range of rates for four age groups: last trimester to newborn, newborn to two years of age, two years to 16 years of age, and older than 16 years of age. CAPCOA and CARB recently recommended the use of 95th percentile breathing rates for the most sensitive age group (less than two years of age) and 80th percentile for all other age groups.
- Fraction of Time at Home (FAH) refers to the estimated amount of time residents stay at home. In past HRAs, the Air District assumed that residents are home 24 hours a day, 7 days a week. OEHHA in its 2015 Risk Assessment Guidance is recommending less than 100% of time based on population and activity statistics. Consistent with OEHHA, the PHP tool incorporates a FAH of 0.73 for 16 year olds and above and one for under 16 to address exposures at local schools in close proximity to emitting facilities.
- Exposure Duration (ED) is the length of time an individual is continuous exposed to air toxics. Previously, the Air District used a 70 year lifetime exposure duration for residents over a 70 year lifespan. Based on updated demographic data, the Air District follows OEHHA recommendation of 30 year exposure duration, consistent with US EPA, for residents.

Table 2: Summary of the factors used in the screening tool.

Factor	Units	Age Groups			
		Last Trimester to Newborn	0 to 2 years old	2 to 16 years old	>16 years
Daily breathing rates (DBR)	L/kg-day	361	1090	572	261
Age Sensitivity (ASF)	unitless	10	10	3	1
Fraction of time at home (FAH)	unitless	1	1	1	0.73
Exposure duration (ED)	years	0.25	2	14	14

The equation used to calculate the dose for the inhalation pathway is as follows:

$$Dose_i = \left(CF \times EF \times \sum_j^{30\ years}\{C_{i,j} \times DBRj \times FAHj \times EDj \times ASF_j\}\right) \div AT$$

Where:

$Dose_i$	=	Accumulated dose for an individual breathing carcinogen *i* for 30 continuous years (mg/kg-day)
CF	=	conversion factor (10^{-6} mg-m^3/µg-L)
EF	=	Exposure frequency (350 days per year[4])
$DBRj$	=	Daily breathing rate during year *j* (L/kg-day)
$FAHj$	=	Fraction of time at home during year *j* (unitless)
ED_j	=	Exposure duration of year *j* (years)
$C_{i,j}$	=	Annual average concentration for pollutant *i* during year *j* (µg/m^3) equal to the emission rate (g/sec) multiplied by the source type Chi/Q (dilution factor ug/m3 per g/sec)
ASF_j	=	Age Sensitivity Factor for year *j*; the value of the factor is higher in early years of exposure (unitless)
AT	=	Averaging time (25,550 days, equivalent to 70 year lifespan)

[4] Screening tool uses an exposure frequency of 350 days per year consistent with OEHHA and EPA guidance. 350 days per year represent the number of days an individual will reside in their home less approximately, two weeks of vacation.

The cancer risk is equal to the dose multiplied by the chemical-specific CPF. In most cases, CPF specific for the inhalation pathways were used. However, some chemicals, in addition to being inhaled, can deposit on the ground in particulate form and contribute to risk through ingestion of soil or through other routes. To account for the additional risks from exposure to non-inhalation pathways, multi-pathway CPFs were used where available from OEHHA. Risks were not estimated for chemicals lacking OEHHA approved toxicity values. The total per million cancer risk is then the sum of the pollutant specific risk values.

The screening tool also evaluated the hazard associated with chronic exposures to non-carcinogenic compounds. The potential for chronic non-cancer hazards is evaluated by comparing the long term exposure level and intake by the chronic reference exposure level (REL). The REL is used as an indicator of potential adverse non-cancer health effects, and refers to a concentration (ug/m3) at which no adverse health effects are anticipated. The RELs used in this tool are published by OEHHA. Noncancer chronic hazard are calculated by dividing the chemical-specific REL by the annual average concentration. The equation for estimating the hazard quotient is:

$$HQ_i = Ci, j \div REL_i$$

Where:

HQ_i	=	Accumulated dose for an individual breathing carcinogen *i* for 30 continuous years (mg/kg-day)
$C_{i,j}$	=	Annual average concentration for pollutant *i* during year *j* (µg/m^3) equal to the emission rate (g/sec) multiplied by the source type Chi/Q (dilution factor ug/m3 per g/sec)
REL_i	=	Chronic noncancer reference exposure level for chemical *i* (mg/kg-day)

Multi-pathway RELs were used, when available from OEHHA, to account for additional exposures through non-inhalation pathways. The hazard index (HI) is the sum of the individual HQs for TACs identified as affecting the same target organ or organ systems. To conservatism, all HQs were summed regardless of target organ.

The modeled screening level impacts are not representative of actual health risks. Rather, the values are upper-bound estimates for assessing whether a site-specific health risk assessment is warranted. The screening approach relies on numerous defaults, conservative assumptions that are not facility specific nor are the estimates reflective of actual cancer risks likely to be experienced by nearby receptors.

BAY AREA AIR QUALITY MANAGEMENT DISTRICT

April 25, 2018

Richard Corey, Executive Officer
California Air Resources Board
1001 "I" Street
Sacramento, CA 95812

RE: Initial Submittal: Technical Assessment to Develop an Initial List of Candidate Communities for the Community Air Protection Program

Dear Mr. Corey,

This letter serves as the Bay Area Air Quality Management District's (Air District) Initial Submittal on "candidate communities" for the state's Community Air Protection Program, as required by the California Air Resources Board. The Community Air Protection Program was established by the state to implement Assembly Bill 617 (C. Garcia, Chapter 136, Statues of 2017). AB 617 directs the state, in consultation with local air districts, to select communities that have a "high cumulative exposure burden" to air pollution. Once selected, these communities then become eligible to work with local air districts on community emission reduction programs and/or community monitoring campaigns.

State law also requires the Air Resources Board to identify priority communities from the full list of candidate communities submitted by local air districts. Identification of priority communities is necessary due to resource limitations, which only allow for a small number of candidate communities to be selected each year to develop emission reduction programs or monitoring campaigns. The state will select communities that will go forward with either action plans or monitoring in the first year of the program on October 1, 2018, with subsequent communities to be selected each year thereafter. State selection of priority communities is to be based on local air district priority community recommendations. The Air District is required to submit recommendations on priority communities to the Air Resources Board by July 31, 2018.

To respond to the Air Resources Board initial submittal information requirements (See Attachment A), a description of all candidate communities for the San Francisco Bay Area is provided below. The Air District's Community Air Risk Evaluation (CARE) program[1] has historically served as the Air District's foundation for identifying communities impacted by and vulnerable to health impacts associated with cumulative air pollution. The identification process, described below, builds on that foundation, and incorporates additional areas identified with new data sources, tools, approaches and community-specific considerations. As required by the state, the Air District has developed an outreach plan and a schedule for working with community members to narrow down the full list of candidate communities to priority recommendations. The Air District's outreach plan, as well as a summary of existing community relationships, is also provided below.

[1] http://www.baaqmd.gov/plans-and-climate/community-air-risk-evaluation-care-program

1. Description of Candidate Communities

As demonstrated in Figure 1, the Air District has identified high cumulative exposure burden areas, or candidate communities, in every county in the San Francisco Bay Area.[2] To identify areas for recommendation to the state, the Air District primarily considered communities that are within the Air District's CARE areas. The Air District also recommends areas not within CARE that have large sources of air pollution or have been identified via statewide screening tools as areas with pollution and/or health burden vulnerability. The Air District also recommends areas that have low life expectancy.[3]

Most candidate community areas in the SF Bay Area are in the region's urban core, with a few locations in more suburban or semi-rural areas. Approximately half of the Bay Area's population live in the identified areas.[4] In general, communities identified as high cumulative exposure burden areas have high levels of environmental exposures and/or experience social or economic disadvantages. They may also have health burdens that increase vulnerability to environmental exposures. Specifically, identified communities experience higher levels of exposure to fine particles, diesel PM, and other pollutants, higher vehicle traffic and related impacts, more asthma emergency room visits, higher rates of cardiovascular disease, greater unemployment, lower educational attainment, lower life expectancy and higher incidences of poverty. These areas are also more racially and ethnically diverse; many areas are communities of color, where Hispanic, African-American and other non-white populations predominately live.

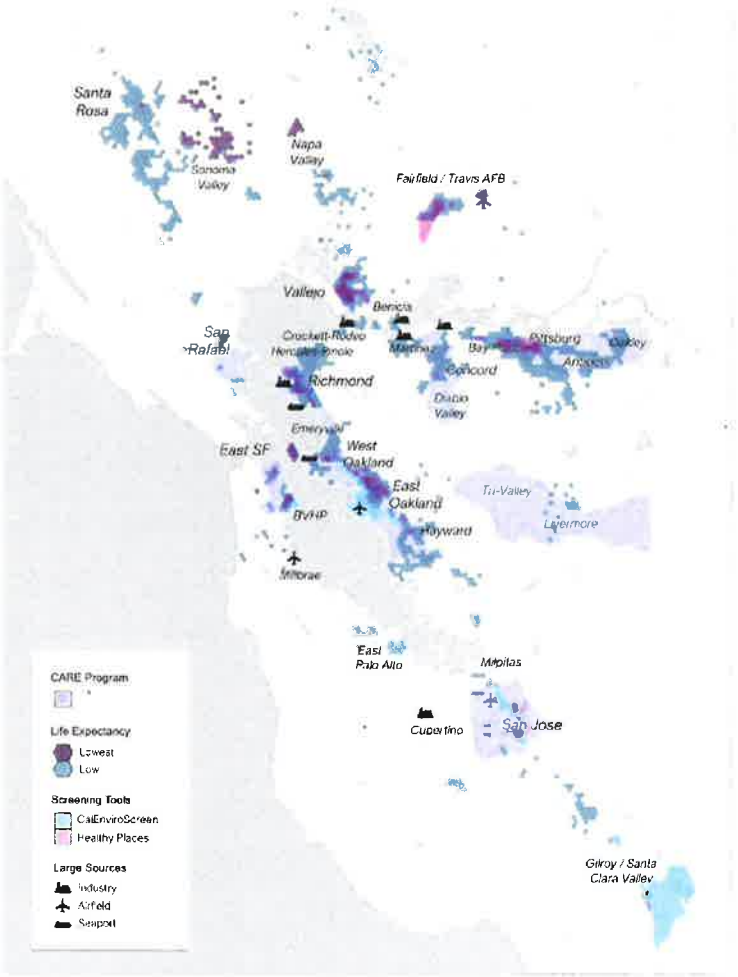


Figure 1: High Cumulative Exposure Burden Communities, SF Bay Area

[2] See Attachment B for full page version of Figure 1
[3] For a full description of the methodology used to identify high cumulative exposure burden areas, see response to question 2.
[4] U.S. Census Bureau

In the North Bay, areas of Sonoma and Solano and Napa Counties have been identified as high cumulative exposure burden areas. In Sonoma County, portions of Santa Rosa and in the rural areas of Sonoma Valley have been identified, primarily due to low life expectancy. In Marin County, areas of San Rafael have been included as high cumulative exposure burden areas due to exceedances of the 24-hr $PM_{2.5}$ standards in recent years and low life expectancy. Most of San Rafael is also a designated CARE area.

In Solano County, candidate communities include much of Vallejo, Benicia, and portions of Fairfield. Vallejo is near large industrial facilities and experiences high levels of $PM_{2.5}$ and health vulnerability, according to statewide screening tools; much of Vallejo is a designated CARE area and experiences low life expectancy. Benicia is impacted by petroleum refining facilities. Areas in Fairfield experience high cumulative health and exposure burden, have low life expectancy and are impacted by highway traffic and Travis Air Force Base.

In the East Bay, in Contra Costa County, along the Highway 4 corridor, areas in both Pittsburg and Antioch, as well as portions of Bay Point, Oakley and Brentwood, have been identified as having high cumulative exposure burden. Communities along the Highway 4 corridor experience high levels of traffic emissions, are in a designated CARE area, and have lower life expectancy, as well as health and exposure burden, as identified in statewide tools.

In western Contra Costa County, communities from El Cerrito to Crockett, including most of Richmond, North Richmond, San Pablo, Pinole, Hercules, and Rodeo, are also identified as high cumulative exposure burden areas. Richmond and Rodeo are home to petroleum refining facilities, and numerous other industrial, waste, goods movement and rail facilities. The Richmond- San Pablo area is in the region's CARE program, and experience low life expectancy.

In central Contra Costa County, along the Interstate 680 corridor, areas of Concord, Martinez, Pleasant Hill and Walnut Creek are identified as high cumulative exposure burden areas. Petroleum refining facilities impact Concord and Martinez communities, while heavy traffic impacts this entire region of the County. This part of central Contra Costa County, along I-680 is also in the region's CARE program. Areas around Concord and Martinez experience lower life expectancy. In the southern portion of the county, areas of north San Ramon, along Interstate 680, just north of the I-680 and I-580 interchange, are also included as candidate high cumulative exposure burden areas, as they fall within the Air District's CARE boundaries and have high ozone concentrations. The San Ramon area also experiences high levels of freeway traffic and associated impacts.

In northern and eastern Alameda county, along the I-680 and I-580 interchange, and along the I-580 corridor, areas in Dublin, Pleasanton and Livermore have been identified based on having the highest ozone concentrations, and therefore being a designated CARE area. Areas around Livermore also experience low life expectancy.

In western Alameda County, the I-580, I-237 and I-80 corridors, including portions of Hayward, San Leandro, large segments of Oakland, Emeryville and up the I-80 corridor, through Berkeley and Albany, have been identified as high cumulative exposure burden

areas. The Port of Oakland, Oakland Airport, a concentration of indirect and magnet sources, and railyards are all located in these communities. Virtually all the identified communities in western Alameda County are also in the Air District's CARE program, experience very low life expectancy, and pollution and health burden vulnerabilities, as identified in statewide tools.

In San Francisco County, communities in eastern San Francisco, including areas of the Tenderloin, Chinatown and Bay View Hunters Point are CARE areas and experience low life expectancy, and therefore have been designated as high cumulative exposure burden areas. Eastern San Francisco is impacted by high traffic freeways and railyards, in addition to numerous smaller sources of air pollution. Eastern San Francisco has pockets of poverty, very low employment and higher levels of diesel PM exposure.

On the Peninsula, in San Mateo County, portions of Millbrae, Redwood City and East Palo Alto have been identified as high exposure burden areas. San Francisco Airport and high freeway traffic volumes impact the Millbrae area. In addition, Millbrae, as well as areas in Redwood City and East Palo Alto, experience low life expectancy.

In Santa Clara County, in the South Bay, most of San Jose, areas near Alviso and much of Cupertino are identified as high cumulative exposure areas. Large sources in or near these areas include a cement manufacturer, power plants, water treatment plants, and landfills, in addition to major freeways and distribution centers. The San Jose area is also a designated CARE area, and there are numerous pockets of low life expectancy. The Gilroy area has also been identified due to high cumulative health and pollution burdens, as indicated by statewide screening tools. A water treatment plant, and steel and concrete plant impact the Gilroy area, in addition to mobile source emissions from major freeways and agricultural equipment.

Specific community boundaries for each of the areas described above will be determined in partnership with communities - as the Air District works with community members to identify priority areas, and on specific community monitoring campaigns and/or emission reduction programs.

2. Data Used to Identify High Cumulative Exposure Burden Areas

To identify candidate communities that experience high cumulative exposure burden in the SF Bay Area, the Air District considered geographic areas that fell into one of four categories: 1) the Air District's CARE areas; 2) areas with large sources of air pollution; 3) areas identified via statewide screening tools, including both CalEnviroscreen 3.0 and the California Healthy Places Index; and 4) areas with low life expectancy.

Air District CARE Program

The Air District first initiated a comprehensive program to address regional disparities in air pollution exposure and health effects in 2006. The Community Air Risk Evaluation (CARE) program is used to identify areas within the Bay Area where air pollution is most

contributing to negative health impacts and where populations are most vulnerable to air pollution.

Communities designated under the CARE Program have been identified using modeled concentrations of toxic air contaminants to estimate cancer risk and using increased mortality and illnesses from modeled and measured fine particulate matter ($PM_{2.5}$) and ozone above levels experienced by other Bay Area communities. Population vulnerability was accounted for in estimating health impacts from air pollution by using a community's existing baseline rates of mortality and illnesses (from health records) to determine increases in mortality and illness from air pollution. Areas with episodic "exceedances" of ambient air quality standards for particulate matter or ground-level ozone were also identified through the CARE program.

Large Sources

Communities located near, or substantially impacted by large industrial sources and/or large goods movement facilities and other concentration of mobile sources, such as petroleum refining facilities, cement-kilns, rail yards, seaports and/or airports are also included in the Air District's recommendation for high cumulative exposure burden areas. Some communities in the Bay Area's recommended universe of high cumulative exposure burden areas that have large sources include: Vallejo, Benicia; Crockett-Rodeo; Cupertino; Fairfield; Hercules-Pinole; Richmond, Martinez, Millbrae; Milpitas; Oakland; and San Jose.

Statewide Screening Tools

CalEnviroScreen[5] is a mapping tool that uses environmental, health and socioeconomic information from state and federal government sources to identify California communities that are most affected by multiple sources of pollution, and where people are especially vulnerable to pollution's effects. CalEnviroScreen uses environmental, health, and socioeconomic data to produce scores for every census tract in the state. The scores are mapped so that different communities can be compared. Census tracts in the Bay Area that were ranked within the top 25 percent of statewide scores are included in the Air District's identification of high cumulative exposure burden areas.

The California Healthy Places Index[6], developed by the Public Health Alliance of Southern California, includes diverse non-medical economic, social, political and environmental factors that influence physical and cognitive function, behavior and disease. The total score is used to screen for places with higher health burden. Census tracts in the Bay Area that rank within the top 25 percent of statewide scores are included in the Bay Area's recommendation for high cumulative exposure burden areas.

Life Expectancy at Birth

Communities with low life expectancy at birth are also included in the Air District's submittal of high cumulative exposure burden areas. Life expectancy data was obtained

[5] https://oehha.ca.gov/calenviroscreen
[6] http://healthyplacesindex.org/

from the California Healthy Places Index project. The average expected lifespan for a person born in the Bay Area in 2010 varies widely by community, generally ranging from 70 to 90 years. Approximately one-quarter of the Bay Area's population was identified as residing in a community with low average life expectancy, defined as 80 years or less.

3. Type of Criteria Used to Select Priority Communities

To select priority communities from the universe of high cumulative exposure burden areas, the Air District is considering air pollution source characteristics and air pollution exposures, including from particulate matter, ozone, and toxic air contaminants. The Air District is also considering health burden and vulnerability factors that may lead to health sensitivities, including low life expectancy at birth.

4. List of All High Cumulative Exposure Burden Areas Considered as Candidates

All high cumulative exposure burdens areas in the Bay Area that were considered as candidate communities have been included in this submittal. All candidate communities are described in response to item 1, above and depicted in Attachment B.

5. Outreach Plan to Select Priority Communities

Below is a summary of an outreach plan, or outreach events, the Air District will hold to ensure community participation in the implementation of AB617 in the San Francisco Bay Area, especially with the identification of high cumulative exposure burden communities, and the selection of priority communities.

2018 Monthly Activities

January

- Hold first regional meeting to inform key stakeholders about AB6 17 and the Community Air Protection Program.
- Update Air District website and online engagement tool, Open-Air Forum, with community selection process information and send e-blast to list-serve for community nominations. Begin planning community meetings in the spring.

February

- Online survey through Open Air Forum on community selection criteria for high cumulative exposure burden "universe."
- Consult key stakeholders, including Air District Board, to inform planning of Spring workshops.
- Participate in CARB Bay Area Technical Summit and CARB Air Grants Program meetings on February 22nd.
- Contact Counties and/or Cities to solicit assistance with identifying venues, key stakeholders, and outreach lists.

March

Develop and finalize locations and dates for community meetings in the following 11 areas based on the preliminary list of candidate communities. The community listed after dates below is the location where the meeting will be held, while communities in parenthesis are the communities who are invited to attend.

- **March 28**: San Leandro (San Leandro, Hayward, East Oakland)
- **April**: Vallejo (Vallejo, Benicia, Crocket, Fairfield)
- **April**: Pittsburg (Pittsburg, Bay Point, Antioch, Brentwood, Oakley, Bethel Island)
- **April**: Pleasant Hill (Martinez, Clyde, Concord, Pleasant Hill, Pacheco, Walnut Creek)
- **May**: San Pablo (Richmond, North Richmond, San Pablo, Pinole, Hercules, Rodeo)
- **May:** Tri Valley (Livermore, Pleasanton, Dublin, San Ramon)
- **May**: San Jose (Alviso, Redwood City, East Palo Alto, Cupertino, Milpitas, Fremont, Gilroy, San Jose)
- **May:** Fairfield (Fairfield, Napa, and surrounding area)
- **June**: Santa Rosa (Marin City, Canal District, Santa Rosa, San Rafael)
- **June**: Oakland (Alameda, Albany, Berkeley, Emeryville, Oakland)
- **June**: San Francisco, South San Francisco (Marin, San Francisco)

Meeting goals:

- Present information and background of AB617
- Begin to prioritize all candidate communities into list for years 1 – 5 priority communities
- Begin to identify potential local partners and relevant stakeholders
- Solicit stakeholder guidance on community selection and grants

April

- Reach out to community stakeholders in each planned workshop area.
- Work together with community stakeholders to craft each local agenda.
- Hold three local meetings: Vallejo, Pittsburg, Pleasant Hill

May

- Reach out to community stakeholders in each planned workshop area.
- Work together with community stakeholders to craft each local agenda.
- Hold four local meetings: San Pablo, Tri-Valley, San Jose, Fairfield

June

- Reach out to community stakeholders in each planned workshop area.
- Work together with community stakeholders to craft each local agenda.
- Hold three local meetings: Santa Rosa, Oakland, San Francisco
- Summarize feedback from local meetings and Open Air Forum
- Hold regional meeting for final input on priority communities

July

- Summarize feedback from local meetings and Open Air Forum.
- Begin local engagement with years 2 – 5 communities.

6. Community Relationships in High Cumulative Exposure Burden Areas

The Air District has a long history of engaging with local communities in the region, and specifically in communities within identified high cumulative exposure burden areas. Over the years the Air District has conducted research, provided grants, developed plans, held workshops for rules, provided information and education, conducted outreach, provided sponsorships, conducted special air monitoring studies, and other community engagement activities. Below is a preliminary list of the Air District's community partners in high cumulative exposure burden communities. The Air District will seek to expand and enhance community partnerships as we implement AB 617.

Pittsburg, Bay Point, Antioch Area:

- Ambrose District
- La Clinica de La Raza
- Pittsburg Freedom Breathers
- Pittsburg Unified School District

Benicia Area:

- Benicians for a Safe and Healthy Community
- Citizens Climate Lobby of Contra Costa
- Interfaith Council of Contra Costa

Berkeley Area:

- Community Science Institute
- West Berkeley Community Alliance
- Global Community Monitor
- Communities for a Better Environment

Concord:

- Center for Human Development
- Monument Crisis Center
- Monument Impact
-

Crocket, Rodeo, Hercules Area:

- Citizens Climate Lobby of Contra Costa
- CRUDE
- Interfaith Council of Contra Costa
- P66 Fenceline Committee
- Rodeo Citizens Association

Livermore, Pleasanton, San Ramon, Dublin Area:

- Organizing for Action

Martinez Area:

- Local residents

Oakland Area:

- Bay Planning Coalition
- Breakthrough Communities
- Communities for a Better Environment
- Earth Justice
- East Oakland Building Healthy Communities
- East Oakland Collective
- Higher Ground Neighborhood Development Corp
- Idle-Free Oakland
- Mujeres Unidas
- Planting Justice
- Prescott-Joseph Center
- Rooted in Resilience
- Rose Foundation/New Voices Are Rising
- Urban Releaf
- Unity Council
- West Oakland Environmental Indicators Project
- West Oakland Health Collaborative

Richmond Area:

- APEN
- Citizens Climate Lobby of Contra Costa
- Communities for a Better Environment
- Generacion Vision y Futuro
- Neighborhood House of North Richmond
- North Richmond MAC
- Interfaith Council of Contra Costa
- Richmond Progressive Alliance
- Sunflower Alliance
- 350 Bay Area
- Rich City Rides
- RYSE
- Healthy Richmond
- The Latina Center
- West County Toxics Coalition

San Francisco Area:

- BVHP Advocates
- GreenActionBrightline
- EBHP EJ Response Task Force

- Hunters Point Families
- PODER
- Literacy for Environmental Justice
- Rafiki Coalition

San Jose Area:

- Sustainable Silicon Valley
- San Jose Green Ninja
- Boys and Girls Club

San Leandro, Hayward Area:

- Barbara Lee Center
- Ditching Dirty Diesel Collaborative
- Healthy 880 Coalition

San Rafael Area:

- Canal Alliance
- Canal Welcome Center
- Families for Clean Air
- Huckleberry Youth Programs

Vallejo Area:

- Fresh Air Vallejo
- Community Air Network
- Vallejo Activists

Milpitas Area:

- Milpitas Odor Group
- South Bay Eco Citizens

Cupertino Area:

- Citizens Against Pollution
- Breathe California
- Bay Area for Clean Environment

East Palo Alto:

- Youth United for Community Action

Regional Organizations:
CA Cleaner Freight Coalition, Center for Environmental Health, Greenlining Institute, TransForm, Sunflower Alliance, Air Watch Bay Area, Sierra Club, Brightline Defense, Citizens Climate Lobby, Friends of the Earth, 350 Bay Area, League of Women Voters, Regional Asthma Management and Prevention, Local Clean Energy Alliance, APEN, Rooted in Resilience, Breathe California, Families for Clean Air, Vision y Compromiso, Breakthrough Communities

7. Additional Information: Information Submitted by Community Members

On January 31st, 2018 the Air District hosted a kick-off meeting attended by more than 60 members of the public representing a variety of stakeholder groups including, but not limited to, community-based organizations, residents, business/industry, academia, local, state and regional government, and health professionals. At this meeting, attendees learned about AB 617 from a panel comprised of Air Resources Board and Air District staff and community-based clean air advocates.

During the question and answer portion of the event, attendees shared ideas and concerns regarding AB 617. Summarized below are only the comments shared regarding candidate communities, or community selection and/or priorities:

- Vallejo: Vallejo is an impacted community and should be included as a priority candidate community. *Air District Note: Vallejo is included as a candidate community.*

- Benicia: Benicia is an impacted community and should be included as a candidate community. *Air District Note: Benicia is included as a candidate community.*

- Milpitas: Milpitas is an impacted community and should be included as a candidate community *Air District Note: Milpitas is included as a candidate community.*

- Bay Area: The Air District should consider monitoring campaigns in areas with high levels of residential wood burning.

- Bay Area: The Air District should prioritize communities in which there is community readiness for action. Communities with engaged partners and existing infrastructure to hold the demands of being an AB 617 Community.

After the Air District's kick-off meeting, the public had the opportunity to learn about and weigh in on the methods used to identify candidate communities through an online community engagement tool called Open Air Forum. As of March 26th, close to 150 unique visitors viewed Open Air Forum and 22 of them responded to a survey. The survey asked respondents to rate their level of support for the methods proposed to identify candidate communities. The respondents overwhelmingly support the use of CARE (79 percent), additional impacts (79 percent), and other large sources (79 percent).

Respondents were asked to provide additional criteria that the Air District should consider, respondents recommend that the Air District consider:

- Odors
- Heavy idling
- History of regulatory violations
- Income, race, and other factors that magnify health impacts
- Historical contamination: military bases & heavy industry

Respondents were also provided the opportunity to recommend a community that was not captured by our proposed methods. Seven out of the twenty-two respondents

recommended the following communities: Vallejo, Mare Island, Pt. Richmond, Rodeo-Crocket, Benicia, Alviso and parts of Napa. All recommended communities are already included as Air District candidate communities.

Sincerely,

Jack P. Broadbent
Air Pollution Control Officer

cc: Laura Zaremba-Schmidt, California Air Resources Board
Karen Maglian, Division Chief, California Air Resources Board
Veronica Eady, Assistant Executive Officer, California Air Resources Board

Attachment A: Air Resources Board, Initial Submittal Information Requirements

Initial submittal: Technical assessment to develop an initial list of candidate communities
Due: April 30, 2018

Air districts submitting communities for consideration must provide information on the following elements in the initial submittal:

1) Provide specific information for each candidate community; including community description, identifying characteristics, and/or preliminary geographic boundaries.

2) Describe which data sources, tools, and approaches, including community-specific considerations, the air district used to assess high cumulative exposure burden (toxics and/or criteria pollutants) for this community recommendation process. An assessment using CalEnviroScreen 3.0 should be performed and the results provided. We expect many districts will use additional tools for analysis. If additional data sources, tools, and/or approaches are considered the submittal should include a description of the additional data sources (i.e., detail, refinement, representativeness) in the air district's response when discussing each community recommended or being considered.

3) Describe the type of criteria the air district will use to prioritize the candidate communities considered in their region. Submit any relevant information that may be used to make its 2018 recommendation.

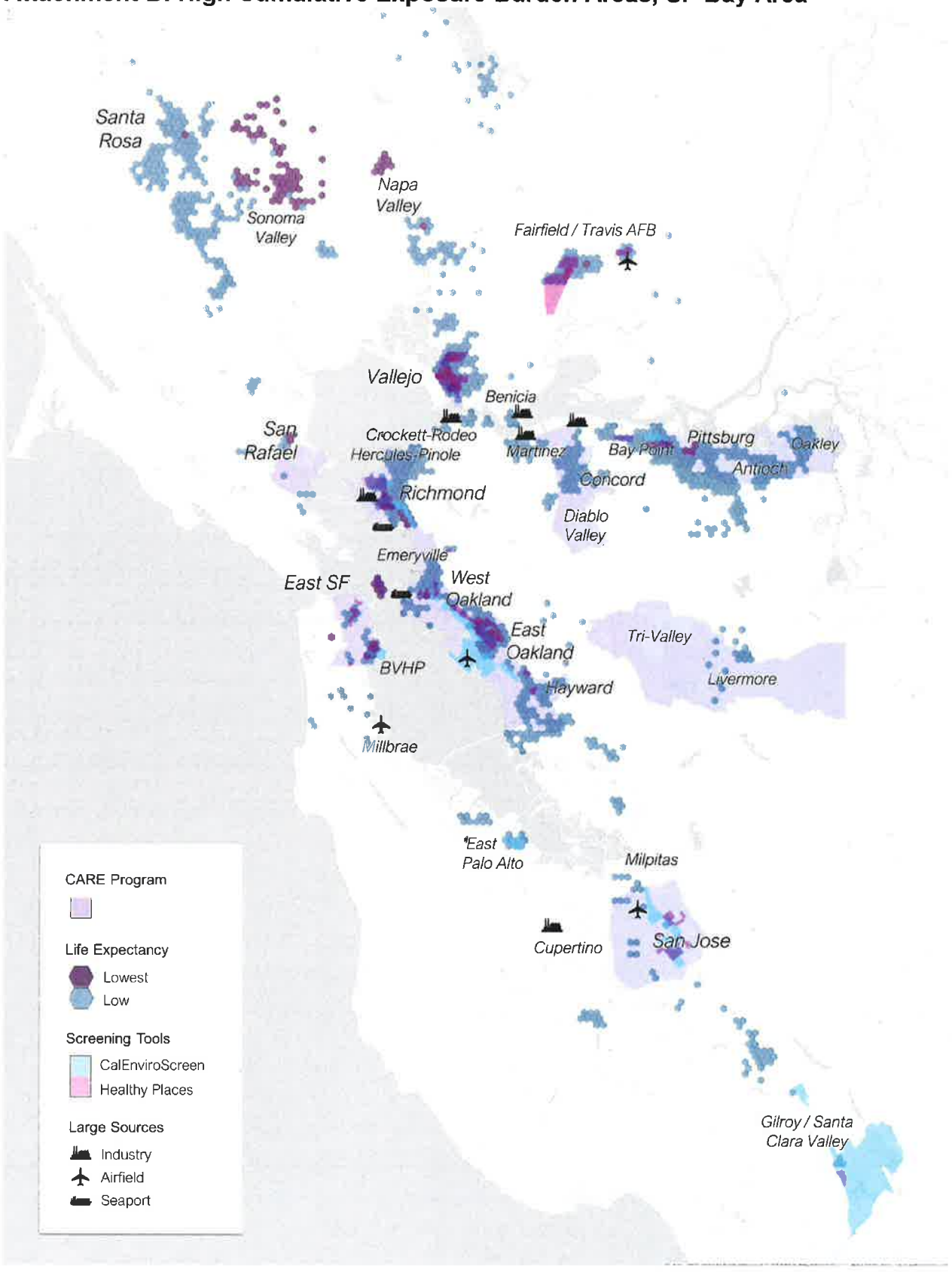
4) Provide a list of all of the communities with high cumulative exposure burdens that were considered as candidates and provide a brief description of each community.

5) Describe the proposed public outreach approach and schedule to move from the preliminary list to the final recommendations for 2018.

6) Describe the air district's relationships with members of the recommended communities or community-based organizations located in the recommended communities.

7) Any additional information, including information submitted by community members, that helped inform the air district recommendations.

Attachment B: High Cumulative Exposure Burden Areas, SF Bay Area



Particulate Matter:
Spotlight on Health Protection

Advisory Council Particulate Matter Reduction Strategy Report

submitted to the Air District Board of Directors for review and consideration

December 16, 2020

Chair Stan Hayes
Dr. Severin Borenstein
Dr. Michael Kleinman
Dr. Tim Lipman
Dr. Jane Long
Dr. Linda Rudolph
Dr. Gina Solomon

TABLE OF CONTENTS

STATEMENT FROM THE EXECUTIVE OFFICER

Thank you for your interest in the Bay Area Air Quality Management District Advisory Council's *Particulate Matter Reduction Strategy Report*.

This report reflects the Bay Area Air Quality Management District's (Air District) recognition of the urgent need to reduce health impacts and health disparities from exposure to particulate matter (PM) at a time when federal leadership is retreating from this responsibility.

Under the Clean Air Act, the United States Environmental Protection Agency (U.S. EPA), with the assistance of the Clean Air Scientific Advisory Committee (CASAC), must review the latest scientific research and the health impacts of air pollutants regulated under the National Ambient Air Quality Standards (NAAQS). Recognizing the scope and significance of their work, the CASAC created a PM Review Committee to review the breadth of air quality science and provide expert insight.

However, in late 2018, the U.S. EPA, disregarding the science and the health impacts of air pollution, without notice disbanded the PM Review Committee. The work of the PM Review Committee, which was to review the U.S. EPA's Integrated Science Assessment on Particulate Matter, was left undone.

The body of scientific research and the guidance of experts is crucial in setting priorities and grounding new and innovative approaches to reducing particulate matter exposure. As an Air District, charged with improving air quality and public health, it has become our responsibility to step into the void created by the federal government and push these critical efforts forward.

Beginning in 2019, we turned to our Advisory Council to close this leadership gap and use its scientific expertise to help set the agenda for improving air quality. The Advisory Council has heard from experts around the country, including members of the disbanded PM Review Committee, as well as industry representatives and local community members and environmental activists who spoke about the lived impacts of exposure to particulate matter. Following these presentations and thoughtful deliberations, the Advisory Council has developed a roadmap to help guide us toward our common goal of a healthier Bay Area.

They have done this work in unprecedented times. Over this past year, we have grappled with a worldwide pandemic that has reshaped the way we live, work, educate, and socialize. The pandemic has laid bare systemic inequities like access to health care and disparities in health outcomes that disproportionately impact African American and Latinx communities. We have faced unprecedented levels of wildfire particulate matter, which has descended on the region for days, turning our skies orange, impacting public health, and compounding systemic inequities.

Aside from these wildfire events, over the past several decades, we have made significant strides toward cleaner air. More recently, groundbreaking programs like the Community Air Risk Evaluation Program, the Community Health Protection Program, and work done in response to Assembly Bill 617 have concentrated efforts to reduce exposure to air pollutants in the neighborhoods that are most impacted. But there is still more to do. Now, more than ever, as we face rising temperatures, changing climates, and persistent inequity, the Air District's work is imperative to ensure a better quality of life for everyone in the Bay Area.

We thank our Advisory Council members for their time and steadfast dedication. Their leadership is invaluable in helping us recognize immediate steps we can take to reduce particulate matter in the region. We at the Air District remain committed to our public and environmental health mission, as we endeavor together to ensure a healthier Bay Area for every resident and future generations.

Jack P. Broadbent

Executive Officer/Air Pollution Control Officer (APCO)

INTRODUCTION

As the first regional air pollution control agency in the nation, predating U.S. EPA by 15 years, the Air District has led the vanguard on environmental efforts for more than six decades. From establishing the nation's first regional air quality monitoring program and integrated regional air quality ozone model, to developing landmark odor regulations and controls on emissions from numerous sources including aerosol spray products, the Air District has continually pioneered increasingly ambitious, comprehensive, and innovative efforts to improve air quality and protect the health of Bay Area residents.

The events of recent years have made this leadership even more critical. Whereas the establishment of the U.S. EPA in 1970 and subsequent Clean Air Act Amendments had enabled the Air District to rely on the considerable resources of the federal government for scientific research and expertise concerning the health impacts of air quality and federal air quality standards, the current federal administration has abandoned this role. In 2018, the U.S. EPA dismissed, via press release, the expert Particulate Matter Review Panel charged with reviewing its assessment of the most current science.

Facing this federal leadership void and recognizing that particulate matter is a major driver of health risks from Bay Area air quality, the Air District and Advisory Council convened the Particulate Matter Symposium Series. The goal of the series was to clarify the state of the science; outline current and forthcoming Air District work; learn about local community efforts, needs, and priorities; and hear from industry representatives. In particular, the Air District and Advisory Council sought to understand how best to improve air quality conditions for communities that are most at risk.

ADVISORY COUNCIL SYMPOSIUM SERIES

The October 2019 PM Symposium facilitated a discussion among nationally recognized scientists, stakeholders, and the Air District on particulate matter and health impacts. In December 2019, the Advisory Council received presentations from Air District staff on current and forthcoming particulate matter reduction strategies. In May and July, via webcast due to the COVID-19 pandemic, the Advisory Council received presentations from community members and environmental activists on the local environmental health effects of particulate matter, in addition to hearing from local industry representatives who shared their perspectives on the science.

Throughout the past year, in order to further inform Advisory Council deliberations and discussions, Air District staff members and representatives from state-level agencies have also presented to the Advisory Council on particulate matter initiatives, research activities, air quality modeling, and measurement and monitoring efforts.

October 28, 2019

Particulate Matter Symposium: Health Effects, Exposure and Risk

- *300+ registrants; many participated online*
- *Two panels: PM Health Effects & PM Exposure & Risk*
- *9 leading experts*

Keynote speaker - Gina McCarthy

Advisory Council Discussion with Experts

JUNE 29 – JULY 2, 2020

Air and Waste Management Association Panel: Developing a Path Forward for $PM_{2.5}$ Regulation in the Bay Area

Together with Air District staff, Advisory Council members host a panel at the annual Air & Waste Management Association Conference & Exhibition

JULY 31, 2020

Advisory Council Meeting: Regulated Industry Presentations and Air District Presentation on Bay Area PM Modeling-Based Assessments and Next Steps

- *Presentations from Frances Keeler, CCEEB and Dr. Julie E. Goodman on behalf of WSPA*
- *Presentation from Dr. Phil Martien, Air District*

DECEMBER 9, 2019

Advisory Council Meeting: BAAQMD Update on Current and Emerging Efforts on Particulate Matter

FEBRUARY 27, 2020

Community Particulate Matter Discussion

Air District staff met with approx. 30 community members from approx. 16 organizations

MAY 12, 2020

Advisory Council Meeting: Community Presentations and Air District Update on PM Potential Policy Strategies

- *Presentations from Jed Holtzman, MEM, 350 Bay Area and LaDonna Williams, All Positives Possible*
- *Presentation from Greg Nudd, Air District*

OCTOBER 9, 2020

Advisory Council Meeting: *Advisory Council members continue discussions from the July 31, 2020, meeting on reducing fine particulate matter in the region*

NOVEMBER 9, 2020

Advisory Council Meeting: *Advisory Council members continue discussions from the July 31, 2020, and October 9, 2020, meetings on reducing fine particulate matter in the region*

DECEMBER 16, 2020

Joint meeting of the Advisory Council and Board of Directors to present and discuss particulate matter reduction strategy

Having received input from scientific experts, community and environmental activists, industry representatives, and Air District and state air quality staff, and with the benefit of its own expertise, the Advisory Council has developed a series of findings and recommendations to help advance the Air District's mission to achieve a healthier Bay Area by reaching for clean air targets beyond state and federal standards.

This document presents these findings along with a framework for evaluating particulate matter reduction strategies into the future. The report also gathers recommended actions as a roadmap for the Air District to consider as it continues work to lower particulate matter exposure throughout the region.

The particulate matter reduction statements, framework, and recommended actions collectively reflect the new imperative for the Air District to lead the country in utilizing the best science available to set ambitious targets for cleaner air and better protect health in every Bay Area community and neighborhood.

ABOUT THE ADVISORY COUNCIL

The Air District's Advisory Council was created in concordance with guidelines in the California Health and Safety Code (Section 40260-40268). The Advisory Council comprises seven members with expertise in air pollution, climate change, and/or the health impacts of air pollution. The Advisory Council advises and consults with the Board of Directors and the Executive Office on technical and policy matters. In 2019, the Air District asked the Advisory Council to provide expert input and guidance on particulate matter reduction strategies in the Bay Area region. More information and Advisory Council member biographies can be found in Appendix D.

ABOUT THE AIR DISTRICT

The California Legislature created the Air District in 1955 as the first regional air pollution control agency in the country. The Air District is tasked with regulating stationary sources of air pollution in the nine counties that surround San Francisco Bay: Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, southwestern Solano, and southern Sonoma counties. It is governed by a 24-member Board of Directors composed of locally elected officials from each of the nine Bay Area counties, with the number of board members from each county based proportionately on its population.

The Board of Directors oversees policies and adopts regulations for the control of air pollution within the district. The Board of Directors also appoints the Air District's Executive Officer/Air Pollution Control Officer, who implements these policies and gives direction to staff, as well as the Air District Counsel, who manages the legal affairs of the agency. The Air District consists of nearly 400 dedicated staff members, including engineers, inspectors, planners, scientists, and other professionals.

PARTICULATE MATTER REDUCTION STATEMENTS

The Advisory Council has gathered evidence on the current state of particulate matter science and the health impacts and risks of particulate matter exposure. The statements reflecting their findings are provided below, and together ground the Air District's future particulate matter reduction initiatives in science and the interest of public health. These statements are as follows:

PMRS1) Particulate Matter (PM) is the most important health risk driver in Bay Area air quality, both $PM_{2.5}$ as a criteria pollutant and diesel PM as a toxic air contaminant.

PMRS2) The Bay Area has made substantial progress at reducing regional $PM_{2.5}$ levels to meet current $PM_{2.5}$ standards; however, 1) more stringent standards would be more health protective; 2) exposures vary substantially across communities; and 3) wildfire smoke increases $PM_{2.5}$ levels substantially above standards.

PMRS3) The current particulate matter national ambient air quality standards (NAAQS) are not health protective.

> *The Advisory Council concurs with the following statement: "Based on scientific evidence, as detailed in Attachment B [of our letter], the [Independent Particulate Matter Review Panel] finds that the current suite of primary fine particle ($PM_{2.5}$) annual and 24-hour standards are not protective of public health. Both of these standards should be revised to new levels, while retaining their current indicators, averaging times, and forms. The annual standard should be revised to a range of 10 µg/m^3 to 8 µg/m^3. The 24-hour standard should be revised to a range of 30 µg/m^3 to 25 µg/m^3. These scientific findings are based on consistent epidemiological evidence from multiple multi-city studies, augmented with evidence from single-city studies, at policy-relevant ambient concentrations in areas with design values at and below the levels of the current standards, and are supported by research from experimental models in animals and humans and by accountability studies." (Independent Particulate Review Panel Letter on Draft EPA PM Policy Assessment, October 2019).*

PMRS4) More stringent standards to reduce exposures are urgently needed, and, if met, would save thousands of lives in the U.S. and many Bay Area lives each year.

PMRS5) There is no known threshold for harmful $PM_{2.5}$ health effects; thus, it follows that additional reductions of $PM_{2.5}$ concentrations will achieve additional public health benefits.

PMRS6) An Air District guideline "target" below the current PM2.5 NAAQS is warranted to protect public health; if the Air District were to set that target at an annual average of as low as 8 µg/m3, U.S. EPA's $PM_{2.5}$ NAAQS risk assessment provides scientific evidence that annual average targets in that range would save additional lives.

PMRS7) Although a large fraction of PM2.5 is regionally contributed, substantially elevated PM2.5 exposures can occur in locations adjacent to local PM sources. Therefore, controlling emissions in these local impacted areas is of primary importance.

PMRS8) Wildfire PM is a serious contributor to PM health effects; early health studies are of concern; more research on acute and sub-chronic effects is ongoing and urgently needed. Wildfire PM exposure is projected to increase in duration and intensity, due to climate change, and this justifies greater efforts to reduce controllable sources of PM to reduce overall health risk.

PMRS9) Some species of PM may be more dangerous than others; as yet, no PM species can be exonerated.

PMRS10) Ultrafine particles (UFP), which are present in the air in large numbers, pose a health risk, but are not adequately monitored. They generally enter the body through the upper and lower respiratory tract and can translocate to essentially all organs. Compared to fine particles ($PM_{2.5}$), they cause more pulmonary inflammation per unit mass, and are retained longer in the lung.

FRAMEWORK FOR EVALUATING PARTICULATE MATTER REDUCTION STRATEGIES

As the Air District approaches the task of reducing particulate matter in the Bay Area, strategies under consideration should be evaluated using the following framework with particular priority given to PM reductions in communities that are most heavily impacted, and especially recognizing the Board's unanimous adoption of Resolution 2020-08, "Condemning Racism and Injustice and Affirming Commitment to Diversity, Equity, Access and Inclusion."

F1) The Air District should move as quickly as possible to take maximal feasible action within its authority to reduce emissions from PM sources, prioritizing the most impacted areas.

F2) PM reduction strategies should prioritize those measures that are most effective in reducing exposure and improving public health and health equity in the most impacted areas.

F3) Local strategies should account for the fact that the most effective exposure reduction measures may differ across communities, due to varying source mix and size, ambient PM concentration levels, physical circumstances (e.g., meteorology, terrain), and other relevant factors.

F4) The Air District should focus PM reduction in areas with elevated exposures, health vulnerability, and those areas with increased impacts and sensitive populations (e.g., U.S. EPA identifies children, non-white, low socioeconomic status, elderly).

F5) PM reduction strategies for highly-impacted communities must include control of the cumulative impact of regional (Bay Area-wide), local (community-level), and localized hot-spot (block-level) sources.

F6) PM reduction strategies should include emission reduction measures for both primary PM and secondary PM formed in the air (e.g., emissions of precursor ROG, NOx, NH_3, and SO_2).

F7) PM reduction strategies will need to address multiple source categories with a wide range of emission reduction measures, and may vary with location; there are no single, universal solutions.

RECOMMENDED ACTIONS

The Advisory Council, in consideration of input from scientists, Air District staff, and industry and community representatives, have identified several actions the Air District can take to reduce particulate matter in the region. These recommended actions are categorized into key priorities reflected in the Particulate Matter Reduction Statements and Framework. Recommended actions include, but are not limited to, the following:

ESTABLISH MORE HEALTH PROTECTIVE TARGETS

RA1) The Air District should establish $PM_{2.5}$ concentration targets consistent with findings based on scientific evidence (e.g., an annual average of as low as 8 µg/m^3).

RA2) Advocate for U.S. EPA and the California Air Resources Board to establish more stringent air quality standards for PM.

RA3) Continue efforts to designate fine PM as a toxic air contaminant.

ADDRESS IMPACTED COMMUNITIES

RA4) Continue to develop strategic action plans for impacted communities. Ensure that these plans evaluate and choose actions based on their impact on reaching the lower air quality targets that we have recommended.

RA5) PM action plans should include best available methods that are feasible for reducing PM emissions and exposures for stationary, area, mobile, and indirect sources of PM.

RA6) Conduct community-level exposure and health impact assessments with local engagement for all highly-impacted communities.

RA7) Evaluate and strengthen implementation and enforcement of programs and rules (including Rule 11-18) to reduce exposures to $PM_{2.5}$ (including diesel PM) and ensure necessary community-specific resources to do so.

RA8) Develop strategies to consider cumulative community PM impacts in permitting processes.

RA9) Modify Air District permitting regulations to address hyper-localized hot-spot and cumulative PM health risks.

RA10) Evaluate current efforts to prevent "piecemealing" in the permitting process and take actions as needed.

RA11) Identify and further reduce significant sources of condensable PM from refineries.

RA12) Seek changes at state level to expand Air District authority for magnet sources of PM emissions.

RA13) Strengthen rules limiting emissions and trackout of road dust to reduce PM in overburdened communities.

RA14) Seek federal funding for electrification infrastructure, especially for disadvantaged communities.

ADDRESS WILDFIRES

RA15) Further develop and implement strategies including health protective measures and guidance to protect health during wildfire episodes. Such measures and guidance could include: 1) public education; 2) improved real-time monitoring and forecasting models; 3) more comprehensive research to assess short- and long-term health impacts; 4) assessment of the feasibility of strategies to reduce PM exposure in proposed forest management strategies; 5) establishment of clean air shelters (e.g., in schools, community centers, libraries, senior centers, senior living facilities) with power, HVAC/HEPA filters, personal protective equipment (PPE), etc., especially in disadvantaged communities; 6) mobile clean air shelters; and 7) strategies to provide HEPA filters for in-home high risk individuals.

REGIONAL RECOMMENDATIONS

Data:

RA16) Continue working to make air quality data for PM and PM precursors more accessible and timely. Partner with effective platforms (e.g., Purple Air).

RA17) Make current PM speciation data more available. Advocate for U.S. EPA national monitoring guidance and requirements to increase PM speciation.

RA18) Advocate for increased, broader, national monitoring, exposure, and health impact studies of UFP.

Mobile Source:

RA19) Advocate for appropriate federal and state agencies to set improved UFP filtration requirements for on-road vehicles.

RA20) Advocate for improved emission estimation and control methods for emerging source categories (e.g., tires & brakes, road dust).

RA21) Develop, fund, implement, and encourage strategies to reduce vehicle miles traveled (e.g., improved public transit; bicycle and pedestrian infrastructure, facilities, and programs; land use planning; and telework).

RA22) Support California Air Resources Board efforts to electrify trucks and other vehicles.

RA23) Assist local programs to control road dust (e.g., analyze road dust emission rates for local streets).

RA24) Seek stricter off-road mobile source rules from the California Air Resources Board.

Electrification:

RA25) Adopt a rule requiring, and create a program incentivizing, all electric utilities in new construction. Continue to look for opportunities that could include training, incentives, and programs to move our existing built environment to all electric.

RA26) Adopt rules to improve the emissions performance of water heaters and space heaters and require newly-installed heaters and other appliances to be electric.

Other:

RA27) Expand efforts to reduce emissions from commercial cooking equipment such as charbroilers and wood-fired ovens.

RA28) Consider further restrictions on residential wood burning emissions.

ANNOTATED BIBLIOGRAPHY FOR PARTICULATE MATTER REDUCTION STATEMENTS AND FRAMEWORK

PARTICULATE MATTER REDUCTION STATEMENTS

PMRS1) Particulate Matter (PM) is the most important health risk driver in Bay Area air quality, both $PM_{2.5}$ as a criteria pollutant and diesel PM as a toxic air contaminant.

Reference:

- **Bay Area Air Quality Management District: *2017 Clean Air Plan*, online at https://www.baaqmd.gov/~/media/files/planning-and-research/plans/2017-clean-air-plan/attachment-a_-proposed-final-cap-vol-1-pdf.pdf?la=en.**

  The Air District's 2017 Clean Air Plan describes strategies for reducing emissions in order to protect both public health and the environment. Health impacts of particulate matter are described in Chapter 2, "Air Pollution and Public Health." Additionally, Appendix C, "Air Pollution and Health Burden," quantifies this impact on Bay Area residents.

PMRS2) The Bay Area has made substantial progress at reducing regional $PM_{2.5}$ levels to meet current $PM_{2.5}$ standards; however, 1) more stringent standards would be more health protective; 2) exposures vary substantially across communities; and 3) wildfire smoke increases $PM_{2.5}$ levels substantially above standards.

References:

- **U.S. Environmental Protection Agency: *Air Quality Design Values, $PM_{2.5}$ Design Values, 2019,* available online at:**
  https://www.epa.gov/air-trends/air-quality-design-values
  https://www.epa.gov/sites/production/files/2020-05/pm25_designvalues_2017_2019_final_05_26_20.xlsx

  Each year, the U.S. EPA calculates and publishes design values for each criteria pollutant for all the State, Local, and Tribal air monitoring sites in the country. Since the design values can change after the date of publication for a variety of reasons, the information in the design value tables is intended for informational use only and does not constitute a regulatory determination by U.S. EPA as whether an area has attained a NAAQS. This document shows that the 2017-2019 annual $PM_{2.5}$ design values are below the Annual $PM_{2.5}$ NAAQS at every site in the Bay Area.

- ***Bay Area Air Quality Management District: Preliminary Analysis of $PM_{2.5}$ Values With and Without Wildfire Smoke Episodes in 2017 and 2018*, available online at https://www.baaqmd.gov/~/media/files/technical-services/pm-2-5-design-values-re-wildfires/wildfire_pm_impacts_20201006-pdf.pdf?la=en.**

  This document describes the analyses performed by the Bay Area Air Quality Management District to estimate the $PM_{2.5}$ design values without days in 2017 and 2018 impacted by wildfire smoke. This preliminary analysis provides a rough evaluation of how the $PM_{2.5}$ trends would be different without the impact of a few of the largest most recent wildfires. As shown in this document, when days impacted by wildfire are excluded, the 2017-2019 $PM_{2.5}$ design values are below the applicable standards.

- **Bay Area Air Quality Management District: *West Oakland Community Action Plan: Owning Our Air*, online at https://www.baaqmd.gov/community-health/community-health-protection-program/west-oakland-community-action-plan.**

  This plan, shaped by a community-based steering committee, identifies specific air quality challenges in different parts of West Oakland and outlines strategies for reducing local residents' PM exposures. Chapter 5 presents a Technical Assessment that estimates the relative contributions of local and regional sources to PM concentrations, finding that proximity to local sources of PM emissions can substantially elevate exposure levels.

- **Colmer, J., Hardman, I., Shimshack, J. and Voorheis, J., 2020. "Disparities in $PM_{2.5}$ air pollution in the United States." *Science*, 369(6503), 575-578.**

  This study combined 36 years of data across approximately 65,000 census tracts to understand disparities in $PM_{2.5}$ concentration levels. The authors found that, although both overall $PM_{2.5}$ concentration levels and differences between the most and least polluted areas have decreased, disparities in $PM_{2.5}$ concentration levels persist. More-polluted areas did not experience greater relative reductions; rather, proportional decreases have been consistent across vigintiles. The most polluted areas of 1981 remained the most polluted areas of 2016.

- **Environmental Protection Agency: *PM Integrated Science Assessment*, online at https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter, Section 13.3, 13-69 (p. 1902).**

  The U.S. Environmental Protection Agency's 2019 *Integrated Science Assessment for Particulate Matter* reviewed the body of new particulate matter research since 2009 including epidemiological studies, animal toxicological studies, and controlled human exposure studies at PM levels analogous to ambient concentrations in U.S. communities.

  Section 13.3 discusses the relationship of $PM_{2.5}$ to climate. With respect to wildfires, the *Integrated Science Assessment* describes a feedback loop in which warmer temperatures and land use change lead to more frequent wildfires, which in turn can affect precipitation patterns in ways that further increase the likelihood of fires.

- **Wettstein, Zachary S, Sumi Hoshiko, Jahan Fahimi, Robert J Harrison, Wayne E Cascio, and Ana G Rappold. 2018. "Cardiovascular and Cerebrovascular Emergency Department Visits Associated with Wildfire Smoke Exposure in California in 2015." *Journal of the American Heart Association* 7 (8). Am Heart Assoc: e007492.**

  This study examined patterns in hospital emergency department visits in the days following wildfire events across much of California, finding an increased likelihood of cardiovascular and cerebrovascular (stroke) events following nearby wildfires among people over the age of 65, particularly those with underlying cardiovascular conditions.

- **Jones, C.G., Rappold, A.G., Vargo, J., Cascio, W.E., Kharrazi, M., McNally, B., and Hoshiko, S., 2020. "Out-of-Hospital Cardiac Arrests and Wildfire-Related Particulate Matter During 2015–2017 California Wildfires." *Journal of the American Heart Association*, 9(8), p.e014125.**

  This study examined the frequency of cardiac arrests occurring outside a medical setting (e.g. at home, work, or in a public place) in the days following wildfire events in 14 California counties. The authors found that men and women aged 35 or older were more likely to experience sudden cardiac arrest (heart attack) on days with heavy smoke, with risks appearing further elevated for people in lower income groups.

- **Environmental Protection Agency: *PM Integrated Science Assessment*, online at https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter, Section 1.4.1.5, 1-30 (p. 166).**

  The U.S. Environmental Protection Agency's 2019 *Integrated Science Assessment for Particulate Matter* reviewed the body of new particulate matter research since 2009 including epidemiological studies, animal toxicological studies, and controlled human exposure studies at PM levels analogous to ambient concentrations in U.S. communities.

  Section 1.4.1.5 describes how the available evidence supports the conclusion that there is a causal relationship between ambient $PM_{2.5}$ exposure and mortality.

- **Environmental Protection Agency: *Policy Assessment for PM NAAQS* 1/2020, online at https://www.epa.gov/naaqs/particulate-matter-pm-standards-policy-assessments-current-review-0, Section 3.3.2.2, Table 3-7, 3-90 (p. 190) and Table 3-8, 3-91 (p. 191); Section 3.3.3, 3-97 (p. 197).**

  The U.S. Environmental Protection Agency's *Policy Assessment for Review of the PM NAAQS* is intended to serve as a bridge between science and rulemaking, interpreting the findings of the U.S. EPA *Integrated Science Assessment* with respect to existing and potential policy.

  Section 3.3.2.2., Table 3-7 compares mortality associated with $PM_{2.5}$ exposure at the current 12 $\mu g/m^3$ standard with mortality risk at potential standards of 9 $\mu g/m^3$, 10 $\mu g/m^3$, and 11

µg/m^3, and Table 3-8 calculates the number of lives that could be spared and the potential percent reduction in mortality at these lower $PM_{2.5}$ concentrations.

Section 3.3.3. summarizes the document's conclusions, stating that "the current primary $PM_{2.5}$ standards could allow a substantial number of $PM_{2.5}$-associated deaths in the U.S."

- **Xiao Wu, Danielle Braun, Marianthi-Anna Kioumourtzoglou, Francesca Dominici. "Evaluating the Impact of Long-term Exposure to Fine Particulate Matter on Mortality Among the Elderly." *Science Advances*, 2020 DOI: 10.1126/sciadv.aba5692.**

  Using 16 years of data for more than 68.5 million people, this study provides strong evidence of a causal link between long-term exposure to $PM_{2.5}$ concentrations below the current NAAQS and mortality. The authors estimate that an annual standard of 10 µg/m^3 would save more than 143,000 lives in one decade compared to the current 12µg/m^3 standard.

- **Di, Q., Wang, Y., Zanobetti, A., Wang, Y., Koutrakis, P., Choirat, C., Dominici, F. and Schwartz, J.D. (2017). "Air pollution and mortality in the Medicare population." *New England Journal of Medicine*, 376(26), 2513-2522.**

  This large-scale analysis used data from the entire U.S. population over the age of 65 — approximately 61 million people — to investigate associations between mortality and exposure to ambient $PM_{2.5}$ levels as measured by U.S. EPA data, concluding that risk of death rose significantly with $PM_{2.5}$ levels at concentrations below the 12 µg/m^3 NAAQS threshold.

PMRS3) The current particulate matter national ambient air quality standards (NAAQS) are not health protective.

The Advisory Council concurs with the following statement: "Based on scientific evidence, as detailed in Attachment B [of our letter], the [Independent Particulate Matter Review Panel] finds that the current suite of primary fine particle ($PM_{2.5}$) annual and 24-hour standards are not protective of public health. Both of these standards should be revised to new levels, while retaining their current indicators, averaging times, and forms. The annual standard should be revised to a range of 10 µg/m^3 to 8 µg/m^3. The 24-hour standard should be revised to a range of 30 µg/m^3 to 25 µg/m^3. These scientific findings are based on consistent epidemiological evidence from multiple multi-city studies, augmented with evidence from single-city studies, at policy-relevant ambient concentrations in areas with design values at and below the levels of the current standards, and are supported by research from experimental models in animals and humans and by accountability studies." (Independent Particulate Review Panel Letter on Draft EPA PM Policy Assessment, October 2019).

References:

- **Independent Particulate Matter Review Panel: *Final letter to Administrator Wheeler with the IPMRP's recommendations*, October 22, 2019. Available online at https://www.ucsusa.org/meeting-independent-particulate-matter-review-panel**

  This letter, written by the scientists who made up the U.S. EPA's Clean Air Scientific Advisory Committee (CASAC) before it was dismissed without notice in 2018, contains these experts' findings after reviewing the EPA's Integrated Science Assessment (ISA, Reference 2) and Policy Assessment (PA, Reference 3) regarding particulate matter. The panel strongly called for stricter PM standards based on the evidence in the ISA and PA.

- **Environmental Protection Agency: *PM Integrated Science Assessment*, online at https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter, Section 1.4.1.5, 1-30 (p. 166); Section 1.5.3, 1-48 (p. 184); Section 11.1.10, 11-38 (p. 1651) and Section 11.2.4, 11-84 (p. 1697).**

  The U.S. Environmental Protection Agency's 2019 *Integrated Science Assessment for Particulate Matter* reviewed the body of new particulate matter research since 2009 including epidemiological studies, animal toxicological studies, and controlled human exposure studies at PM levels analogous to ambient concentrations in U.S. communities.

  This review demonstrated that PM causes more health problems than previously known, at lower concentrations than previously known, and disproportionately affects vulnerable populations.

  Section 1.4.1.5 describes how the available evidence supports the conclusion that there is a causal relationship between ambient $PM_{2.5}$ exposure and mortality.

  Section 1.5.3 explains the concentration-response relationship observed between $PM_{2.5}$ exposure and health effects, stating that recent studies "continue to provide evidence of a linear, no-threshold relationship between both short- and long-term $PM_{2.5}$ exposure and several respiratory and cardiovascular effects, and mortality."

  Sections 11.1.10 (short-term exposure) and 11.2.4 (long-term exposure) provide further discussion of this concentration-response relationship, evidence regarding its linearity, and the lack of a $PM_{2.5}$ threshold below which deleterious health effects are not observed.

- **Environmental Protection Agency: *Policy Assessment for PM NAAQS* 1/2020, online at https://www.epa.gov/naaqs/particulate-matter-pm-standards-policy-assessments-current-review-0, Section 3.3.2.2, Table 3-7, 3-90 (p. 190) and Table 3-8, 3-91 (p. 191); Section 3.3.3, 3-97 (p. 197).**

  The U.S. Environmental Protection Agency's *Policy Assessment for Review of the PM NAAQS* is intended to serve as a bridge between science and rulemaking, interpreting the findings of the U.S. EPA *Integrated Science Assessment* with respect to existing and potential policy.

In Section 3.3.2.2., Table 3-7 compares mortality associated with $PM_{2.5}$ exposure at the current 12 µg/m^3 standard with mortality risk at potential standards of 9 µg/m^3, 10 µg/m^3, and 11 µg/m^3, and Table 3-8 calculates the number of lives that could be spared and the potential percent reduction in mortality at these lower $PM_{2.5}$ concentrations.

Section 3.3.3. summarizes the document's conclusions, stating that "the current primary $PM_{2.5}$ standards could allow a substantial number of $PM_{2.5}$-associated deaths in the U.S."

PMRS4) More stringent standards to reduce exposures are urgently needed, and, if met, would save thousands of lives in the U.S. and many Bay Area lives each year.

Reference:

- **Environmental Protection Agency: *Policy Assessment for PM NAAQS* 1/2020, online at https://www.epa.gov/naaqs/particulate-matter-pm-standards-policy-assessments-current-review-0, Section 3.3.2.2, Table 3-7, 3-90 (p. 190) and Table 3-8, 3-91 (p. 191); Section 3.3.3, 3-97 (p. 197).**

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  Section 3.3.3. summarizes the document's conclusions, stating that "the current primary $PM_{2.5}$ standards could allow a substantial number of $PM_{2.5}$-associated deaths in the U.S."

PMRS5) There is no known threshold for harmful $PM_{2.5}$ health effects; thus, it follows that additional reductions of $PM_{2.5}$ concentrations will achieve additional public health benefits.

Reference:

- **Environmental Protection Agency: *PM Integrated Science Assessment*, online at https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter, Section 1.5.3, 1-48 (p. 184); Section 11.1.10, 11-38 (p. 1651) and Section 11.2.4, 11-84 (p. 1697).**

  The U.S. Environmental Protection Agency's 2019 *Integrated Science Assessment for Particulate Matter* reviewed the body of new particulate matter research since 2009 including epidemiological studies, animal toxicological studies, and controlled human exposure studies at PM levels analogous to ambient concentrations in U.S. communities.

Section 1.5.3 explains the concentration-response relationship observed between $PM_{2.5}$ exposure and health effects, stating that recent studies "continue to provide evidence of a linear, no-threshold relationship between both short- and long-term $PM_{2.5}$ exposure and several respiratory and cardiovascular effects, and mortality.

Sections 11.1.10 (short-term exposure) and 11.2.4 (long-term exposure) provide further discussion of this concentration-response relationship, evidence regarding its linearity, and the lack of a $PM_{2.5}$ threshold below which deleterious health effects are not observed.

PMRS6) An Air District guideline "target" below the current $PM_{2.5}$ NAAQS is warranted to protect public health; if the Air District were to set that target at an annual average of as low as 8 µg/m^3, U.S. EPA's $PM_{2.5}$ NAAQS risk assessment provides scientific evidence that annual average targets in that range would save additional lives.

References:

- **Environmental Protection Agency: *PM Integrated Science Assessment*, online at https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter, Section 1.4.1.5, 1-30 (p. 166).**

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- **Environmental Protection Agency: *Policy Assessment for PM NAAQS* 1/2020, online at https://www.epa.gov/naaqs/particulate-matter-pm-standards-policy-assessments-current-review-0, Section 3.3.2.2, Table 3-7, 3-90 (p. 190) and Table 3-8, 3-91 (p. 191); Section 3.3.3, 3-97 (p. 197).**

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  Section 3.3.2.2., Table 3-7 compares mortality associated with $PM_{2.5}$ exposure at the current 12 µg/m^3 standard with mortality risk at potential standards of 9 µg/m^3, 10 µg/m^3, and 11 µg/m^3, and Table 3-8 calculates the number of lives that could be spared and the potential percent reduction in mortality at these lower $PM_{2.5}$ concentrations.

  Section 3.3.3. summarizes the document's conclusions, stating that "the current primary $PM_{2.5}$ standards could allow a substantial number of $PM_{2.5}$-associated deaths in the U.S."

- **Xiao Wu, Danielle Braun, Marianthi-Anna Kioumourtzoglou, Francesca Dominici. "Evaluating the Impact of Long-term Exposure to Fine Particulate Matter on Mortality Among the Elderly." *Science Advances*, 2020 DOI: 10.1126/sciadv.aba5692.**

  Using 16 years of data for more than 68.5 million people, this study provides strong evidence of a causal link between long-term exposure to $PM_{2.5}$ concentrations below the current NAAQS and mortality. The authors estimate that an annual standard of 10 $\mu g/m^3$ would save more than 143,000 lives in one decade compared to the current 12$\mu g/m^3$ standard.

- **Di, Q., Wang, Y., Zanobetti, A., Wang, Y., Koutrakis, P., Choirat, C., Dominici, F. and Schwartz, J.D. (2017). "Air pollution and mortality in the Medicare population." *New England Journal of Medicine*, 376(26), 2513-2522.**

  This large-scale analysis used data from the entire U.S. population over the age of 65 — approximately 61 million people — to investigate associations between mortality and exposure to ambient $PM_{2.5}$ levels as measured by U.S. EPA data, concluding that risk of death rose significantly with $PM_{2.5}$ levels at concentrations below the 12 $\mu g/m^3$ NAAQS threshold.

PMRS7) Although a large fraction of $PM_{2.5}$ is regionally contributed, substantially elevated $PM_{2.5}$ exposures can occur in locations adjacent to local PM sources. Therefore, controlling emissions in these local impacted areas is of primary importance.

References:

- **Bay Area Air Quality Management District: *West Oakland Community Action Plan: Owning Our Air*, online at https://www.baaqmd.gov/community-health/community-health-protection-program/west-oakland-community-action-plan.**

  This plan, shaped by a community-based steering committee, identifies specific air quality challenges in different parts of West Oakland and outlines strategies for reducing local residents' PM exposures. Chapter 5 presents a Technical Assessment that estimates the relative contributions of local and regional sources to PM concentrations, finding that proximity to local sources of PM emissions can substantially elevate exposure levels.

- **Colmer, J., Hardman, I., Shimshack, J. and Voorheis, J., 2020. "Disparities in $PM_{2.5}$ air pollution in the United States." *Science*, 369(6503), 575-578.**

  This study combined 36 years of data across approximately 65,000 census tracts to understand disparities in $PM_{2.5}$ concentration levels. The authors found that, although both overall $PM_{2.5}$ concentration levels and differences between the most and least polluted areas have decreased, disparities in $PM_{2.5}$ concentration levels persist. More-polluted areas did not experience greater relative reductions; rather, proportional decreases have been consistent across vigintiles. The most polluted areas of 1981 remained the most polluted areas of 2016.

PMRS8) Wildfire PM is a serious contributor to PM health effects; early health studies are of concern; more research on acute and sub-chronic effects is ongoing and urgently needed. Wildfire PM exposure is projected to increase in duration and intensity, due to climate change, and this justifies greater efforts to reduce controllable sources of PM to reduce overall health risk.

References:

- **Environmental Protection Agency: *PM Integrated Science Assessment*, online at https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter, Section 13.3, 13-69 (p. 1902).**

  The U.S. Environmental Protection Agency's 2019 *Integrated Science Assessment for Particulate Matter* reviewed the body of new particulate matter research since 2009 including epidemiological studies, animal toxicological studies, and controlled human exposure studies at PM levels analogous to ambient concentrations in U.S. communities.

  Section 13.3 discusses the relationship of $PM_{2.5}$ to climate. With respect to wildfires, the *Integrated Science Assessment* describes a feedback loop in which warmer temperatures and land use change lead to more frequent wildfires, which in turn can affect precipitation patterns in ways that further increase the likelihood of fires.

- **Environmental Protection Agency: *Memorandum on Modeling Guidance for Demonstrating Air Quality Goals for Ozone, PM2.5, and Regional Haze, 2018*, available online at https://www3.epa.gov/ttn/scram/guidance/guide/O3-PM-RH-Modeling_Guidance-2018.pdf**

  This U.S. EPA document provides modeling guidance for air quality agencies charged with satisfying federal demonstration requirements. Guidance regarding calculation of PM design values acknowledges: "it is well-established that inter-annual variability in meteorological conditions often leads to year to year differences in design values, even with static emissions levels" (p. 101).

- **Wettstein, Zachary S, Sumi Hoshiko, Jahan Fahimi, Robert J Harrison, Wayne E Cascio, and Ana G Rappold. 2018. "Cardiovascular and Cerebrovascular Emergency Department Visits Associated with Wildfire Smoke Exposure in California in 2015." *Journal of the American Heart Association* 7 (8). Am Heart Assoc: e007492.**

  This study examined patterns in hospital emergency department visits in the days following wildfire events across much of California, finding an increased likelihood of cardiovascular and cerebrovascular (stroke) events following nearby wildfires among people over the age of 65, particularly those with underlying cardiovascular conditions.

- **Jones, C.G., Rappold, A.G., Vargo, J., Cascio, W.E., Kharrazi, M., McNally, B., and Hoshiko, S., 2020. "Out-of-Hospital Cardiac Arrests and Wildfire-Related Particulate Matter During 2015–2017 California Wildfires."** ***Journal of the American Heart Association*****, 9(8), p.e014125.**

  This study examined the frequency of cardiac arrests occurring outside a medical setting (e.g. at home, work, or in a public place) in the days following wildfire events in 14 California counties. The authors found that men and women aged 35 or older were more likely to experience sudden cardiac arrest (heart attack) on days with heavy smoke, with risks appearing further elevated for people in lower income groups.

PMRS9) Some species of PM may be more dangerous than others; as yet, no PM species can be exonerated.

Reference:

- **Environmental Protection Agency:** ***PM Integrated Science Assessment*****, online at https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter, Section 1.5.4, 1-50 (p. 186).**

  The U.S. Environmental Protection Agency's 2019 Integrated Science Assessment for Particulate Matter reviewed the body of new particulate matter research since 2009 including epidemiological studies, animal toxicological studies, and controlled human exposure studies at PM levels analogous to ambient concentrations in U.S. communities.

  Section 1.5.4, within Section 1.5 "Policy Considerations," reviews the evidence regarding health effects of specific components or sources of PM, such as motor vehicle emissions, coal combustion, and vegetative burning. The authors conclude that the current state of the science does not clearly differentiate health effects resulting from exposure to different components or sources of PM; "the evidence does not indicate that any one source or component is consistently more strongly related with health effects than $PM_{2.5}$ mass."

- **Achilleos, S., Kioumourtzoglou, M.-A., Wu, C.-D., Schwartz, J.D., Koutrakis, P., Papatheodorou, S.I., 2017. "Acute effects of fine particulate matter constituents on mortality: A systematic review and meta-regression analysis."** ***Environment International*** **109, 89–100.**

  This meta-analysis combined data from all relevant studies investigating links between $PM_{2.5}$ particle constituents and mortality through July 2015 (a total of 41 studies covering 142 cities in several world regions). The authors found evidence that exposure to the combustion elements of elemental carbon (EC) and potassium (K), generally recognized as traffic and wood combustion elements respectively, are each associated with increased risk of mortality. They also observed that health effects varied by region.

- **Yang, Y., Ruan, Z., Wang, X., Yang, Y., Mason, T.G., Lin, H., Tian, L., 2019. "Short-term and long-term exposures to fine particulate matter constituents and health: A systematic review and meta-analysis."** ***Environmental Pollution*** **247, 874–882.**

  This meta-analysis reviewed all relevant studies through August 2018 examining mortality and morbidity in relation to exposure to different components of PM. The authors found consistent associations between cardiovascular morbidity and mortality and exposure to black carbon and organic carbon (associated with a range of combustion including motor vehicle emissions and biomass burning). They also found likely associations between cardiovascular health effects and exposure to $PM_{2.5}$ nitrate, sulfate, zinc, silicon, iron, nickel, vanadium, and potassium; and likely associations between respiratory health effects and exposure to $PM_{2.5}$ nitrate, sulfate, and vanadium.

PMRS10) Ultrafine particles (UFP), which are present in the air in large numbers, pose a health risk, but are not adequately monitored. They generally enter the body through the upper and lower respiratory tract and can translocate to essentially all organs. Compared to fine particles ($PM_{2.5}$), they cause more pulmonary inflammation per unit mass, and are retained longer in the lung.

Reference:

- **Environmental Protection Agency:** ***PM Integrated Science Assessment*****, online at https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter, Section 5.5.1, 5-279 (p. 843); Section 5.5.1.1, 5-281, (p.844); Section 5.5.2.3, 5-287 (p. 851)**

  The U.S. Environmental Protection Agency's 2019 Integrated Science Assessment for Particulate Matter reviewed the body of new particulate matter research since 2009 including epidemiological studies, animal toxicological studies, and controlled human exposure studies at PM levels analogous to ambient concentrations in U.S. communities.

  Section 5.5.1 on "Biological Plausibility" describes the biological pathways by which exposure to ultrafine particles (UFP) is understood to affect human health — potentially activating not only respiratory distress but also a range of immune, nervous system, and other reactions, including oxidative stress.

  Section 5.5.1.1 describes the current science with respect to UFP exposure and respiratory injury, inflammation, and oxidative stress. Evidence suggests that short-term exposure to UFP is associated with markers of injury, inflammatory response, oxidative stress, and allergic asthma, which is consistent with epidemiologic evidence linking UFP exposure with asthma-related hospital admissions.

  Section 5.5.2.3 further investigates the connection between UFP and asthma, reviewing conclusions from the 2009 ISA as well as a more recent animal toxicological study. That study, conducted using mice, indicates that UFP penetrates into the deep lung and is associated with allergic inflammation, asthma exacerbation, and oxidative stress.

- **Ohlwein, S., Kappeler, R., Joss, M.K., Künzli, N., Hoffmann, B., 2019. "Health effects of ultrafine particles: A systematic literature review update of epidemiological evidence."** ***International Journal of Public Health*** **64, 547–559.**

  This meta-analysis reviewed 85 recent studies (published 2011 through 2017) of the health effects of ultrafine particles (UFP) in ambient air pollution. The authors found some evidence for increased risk of short-term inflammatory and cardiovascular effects with UFP exposure beyond the expected effects of larger categories of PM.

FRAMEWORK

F1) The Air District should move as quickly as possible to take maximal feasible action within its authority to reduce emissions from PM sources, prioritizing the most impacted areas.

Reference:

- **No citation needed.**

F2) PM reduction strategies should prioritize those measures that are most effective in reducing exposure and improving public health and health equity in the most impacted areas.

Reference:

- **Environmental Protection Agency: *Fine Particulate Matter National Ambient Air Quality Standards: State Implementation Plan Requirements; Final Rule*, online at https://www.govinfo.gov/content/pkg/FR-2016-08-24/pdf/2016-18768.pdf.**

  This U.S. EPA document describes requirements to be met in implementing National Ambient Air Quality Standards for $PM_{2.5}$. Section G, "Measures to Ensure Appropriate Protections for Overburdened Populations," articulates the importance of protecting communities whose health is disproportionately impacted by $PM_{2.5}$ exposure.

F3) Local strategies should account for the fact that the most effective exposure reduction measures may differ across communities, due to varying source mix and size, ambient PM concentration levels, physical circumstances (e.g., meteorology, terrain), and other relevant factors.

Reference:

- **California Air Resources Board: *Community Air Protection Blueprint*, online at https://ww2.arb.ca.gov/capp-blueprint.**

  This state-level document outlines the process for meeting the requirements of California's AB 617 legislation mandating a statewide program to address long-standing air pollution concerns in disadvantaged communities. Designed to address the "unique needs of individual communities" (p. 7), the Blueprint calls for the development of community-specific action plans based on highly localized emissions, exposure, and public health data and guided by steering committees comprising local community members.

F4) The Air District should focus PM reduction in areas with elevated exposures, health vulnerability, and those areas with increased impacts and sensitive populations (e.g., U.S. EPA identifies children, non-white, low socioeconomic status, elderly).

Reference:

- **Environmental Protection Agency: *PM Integrated Science Assessment*, online at https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter, Section 1.5.5, 1-53 through 1-55 (p. 189-191).**

  The U.S. Environmental Protection Agency's 2019 *Integrated Science Assessment for Particulate Matter* reviewed the body of new particulate matter research since 2009 including epidemiological studies, animal toxicological studies, and controlled human exposure studies at PM levels analogous to ambient concentrations in U.S. communities.

  Section 1.5.5 examines evidence concerning differences in health risk from PM exposure among specific sub-populations. Evidence is sufficient to demonstrate that children and nonwhite people are at greater risk of experiencing $PM_{2.5}$ health effects. The evidence also suggests that people with pre-existing health conditions and low socioeconomic status are at increased risk.

F5) PM reduction strategies for highly-impacted communities must include control of the cumulative impact of regional (Bay Area-wide), local (community-level), and localized hot-spot (block-level) sources.

Reference:

- **State of California: AB-617 Nonvehicular air pollution: criteria air pollutants and toxic air contaminants, online at https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB617.**

  This state legislation mandates a statewide program to address long-standing air pollution concerns in disadvantaged communities. California air districts in which such communities are identified are tasked with designing and deploying community-level monitoring programs and exposure reduction strategies.

F6) PM reduction strategies should include emission reduction measures for both primary PM and secondary PM formed in the air (e.g., emissions of precursor ROG, NOx, NH_3, and SO_2).

Reference:

- **Environmental Protection Agency: Our Nation's Air (2020), online at https://gispub.epa.gov/air/trendsreport/2020.**

  This annual report from the U.S. EPA summarizes trends in air quality. In the section titled "Understanding $PM_{2.5}$ Composition Helps Reduce Fine Particle Pollution," the agency emphasizes the importance of tracking the components of secondary PM.

F7) PM reduction strategies will need to address multiple source categories with a wide range of emission reduction measures, and may vary with location; there are no single, universal solutions.

Reference:

- **Environmental Protection Agency: *Fine Particulate Matter National Ambient Air Quality Standards: State Implementation Plan Requirements; Final Rule*, online at https://www.govinfo.gov/content/pkg/FR-2016-08-24/pdf/2016-18768.pdf.**

  This U.S. EPA document describes requirements to be met in implementing National Ambient Air Quality Standards for $PM_{2.5}$. The agency specifies that these rules and regulations apply to "numerous and diverse sources" of harmful emissions (Section B.1, p. 58012).

Particulate Matter:
Spotlight on Health Protection

Appendix A: Annotated Bibliography for Particulate Matter Reduction Statements and Framework

APPENDIX A: ANNOTATED BIBLIOGRAPHY FOR PARTICULATE MATTER REDUCTION STATEMENTS AND FRAMEWORK *(TABLE)*

The annotated bibliography provides scientific reference and informational materials to support the Advisory Council's particulate matter reduction statements and framework for evaluation. These references are also provided within the report.

ID	*PARTICULATE MATTER REDUCTION STATEMENT*	*CITATION #*
PMRS1	Particulate Matter (PM) is the most important health risk driver in Bay Area air quality, both $PM_{2.5}$ as a criteria pollutant and diesel PM as a toxic air contaminant.	1
PMRS2	The Bay Area has made substantial progress at reducing regional $PM_{2.5}$ levels to meet current $PM_{2.5}$ standards; however, 1) more stringent standards would be more health protective; 2) exposures vary substantially across communities; and 3) wildfire smoke increases $PM_{2.5}$ levels substantially above standards.	4 5 9 10 2 e 11 12 2 a 3 a, b 6 7
PMRS3	The current particulate matter national ambient air quality standards (NAAQS) are not health protective. *The Advisory Council concurs with the following statement: "Based on scientific evidence, as detailed in Attachment B [of our letter], the [Independent Particulate Matter Review Panel] finds that the current suite of primary fine particle ($PM_{2.5}$) annual and 24-hour standards are not protective of public health. Both of these standards should be revised to new levels, while retaining their current indicators, averaging times, and forms. The annual standard should be revised to a range of 10 µg/m^3 to 8 µg/m^3. The 24-hour standard should be revised to a range of 30 µg/m^3 to 25 µg/m^3. These scientific findings are based on consistent epidemiological evidence from multiple multi-city studies, augmented with evidence from single-city studies, at policy-relevant ambient concentrations in areas with design values at and below the levels of the current standards, and are supported by research from experimental models in animals and humans and by accountability studies." (Independent Particulate Review Panel Letter on Draft EPA PM Policy Assessment, October 2019).*	2 a, b, d 3 a, b 20

ID	PARTICULATE MATTER REDUCTION STATEMENT	CITATION #
PMRS4	More stringent standards to reduce exposures are urgently needed, and, if met, would save thousands of lives in the U.S. and many Bay Area lives each year.	3 a, b
PMRS5	There is no known threshold for harmful $PM_{2.5}$ health effects; thus, it follows that additional reductions of $PM_{2.5}$ concentrations will achieve additional public health benefits.	2 b, d
PMRS6	An Air District guideline "target" below the current $PM_{2.5}$ NAAQS is warranted to protect public health; if the Air District were to set that target at an annual average of as low as 8 µg/m^3, U.S. EPA's $PM_{2.5}$ NAAQS risk assessment provides scientific evidence that annual average targets in that range would save additional lives.	2 a 3 a, b 6 7
PMRS7	Although a large fraction of $PM_{2.5}$ is regionally contributed, substantially elevated $PM_{2.5}$ exposures can occur in locations adjacent to local PM sources. Therefore, controlling emissions in these local impacted areas is of primary importance.	9 10
PMRS8	Wildfire PM is a serious contributor to PM health effects; early health studies are of concern; more research on acute and sub-chronic effects is ongoing and urgently needed. Wildfire PM exposure is projected to increase in duration and intensity, due to climate change, and this justifies greater efforts to reduce controllable sources of PM to reduce overall health risk.	2 e 8 11 12
PMRS9	Some species of PM may be more dangerous than others; as yet, no PM species can be exonerated	2f 17 18
PMRS10	Ultrafine particles (UFP), which are present in the air in large numbers, pose a health risk, but are not adequately monitored. They generally enter the body through the upper and lower respiratory tract and can translocate to essentially all organs. Compared to fine particles ($PM_{2.5}$), they cause more pulmonary inflammation per unit mass, and are retained longer in the lung.	2 g, h, i 19

ID	FRAMEWORK FOR EVALUATING PARTICULATE MATTER REDUCTION STRATEGIES	CITATION #
F1	The Air District should move as quickly as possible to take maximal feasible action within its authority to reduce emissions from PM sources, prioritizing the most impacted areas.	n.a.
F2	PM reduction strategies should prioritize those measures that are most effective in reducing exposure and improving public health and health equity in the most impacted areas.	16 b
F3	Local strategies should account for the fact that the most effective exposure reduction measures may differ across communities, due to varying source mix and size, ambient PM concentration levels, physical circumstances (e.g., meteorology, terrain), and other relevant factors.	13
F4	The Air District should focus PM reduction in areas with elevated exposures, health vulnerability, and those areas with increased impacts and sensitive populations (e.g., U.S. EPA identifies children, non-white, low socioeconomic status, elderly).	2 c
F5	PM reduction strategies for highly-impacted communities must include control of the cumulative impact of regional (Bay Area-wide), local (community-level), and localized hot-spot (block-level) sources.	14
F6	PM reduction strategies should include emission reduction measures for both primary PM and secondary PM formed in the air (e.g., emissions of precursor ROG, NO_x, NH_3, and SO_2).	15
F7	PM reduction strategies will need to address multiple source categories with a wide range of emission reduction measures, and may vary with location; there are no single, universal solutions.	16 a

REFERENCES

1. **Bay Area Air Quality Management District: *2017 Clean Air Plan*, online at https://www.baaqmd.gov/~/media/files/planning-and-research/plans/2017-clean-air-plan/attachment-a_-proposed-final-cap-vol-1-pdf.pdf?la=en**

   The Air District's 2017 Clean Air Plan describes strategies for reducing emissions in order to protect both public health and the environment. Health impacts of particulate matter are described in Chapter 2, "Air Pollution and Public Health." Additionally, Appendix C, "Air Pollution and Health Burden," quantifies this impact on Bay Area residents.

2. **Environmental Protection Agency: *PM Integrated Science Assessment*, online at https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter**

   a. Section 1.4.1.5, 1-30 (p. 166)
   b. Section 1.5.3, 1-48 (p. 184)
   c. Section 1.5.5, 1-53 through 1-55 (p. 189-191)
   d. Section 11.1.10, 11-38 (p. 1651) and Section 11.2.4, 11-84 (p. 1697)
   e. Section 13.3, 13-69 (p. 1902)
   f. Section 1.5.4, 1-50 (p. 186)
   g. Section 5.5.1, 5-279 (p. 843)
   h. Section 5.5.1.1, 5-281, (p. 844)
   i. Section 5.5.2.3, 5-287 (p. 851)

   The U.S. Environmental Protection Agency's 2019 *Integrated Science Assessment for Particulate Matter* reviewed the body of new particulate matter research since 2009 including epidemiological studies, animal toxicological studies, and controlled human exposure studies at PM levels analogous to ambient concentrations in U.S. communities.

   This review demonstrated that PM causes more health problems than previously known, at lower concentrations than previously known, and disproportionately affects vulnerable populations.

   (a) Section 1.4.1.5 describes how the available evidence supports the conclusion that there is a causal relationship between ambient $PM_{2.5}$ exposure and mortality.

   (b) Section 1.5.3 explains the concentration-response relationship observed between $PM_{2.5}$ exposure and health effects, stating that recent studies "continue to provide evidence of a linear, no-threshold relationship between both short- and long-term $PM_{2.5}$ exposure and several respiratory and cardiovascular effects, and mortality."

(c) Section 1.5.5 examines evidence concerning differences in health risk from PM exposure among specific sub-populations. Evidence is sufficient to demonstrate that children and nonwhite people are at greater risk of experiencing $PM_{2.5}$ health effects. The evidence also suggests that people with pre-existing health conditions and low socioeconomic status are at increased risk.

(d) Sections 11.1.10 (short-term exposure) and 11.2.4 (long-term exposure) provide further discussion of this concentration-response relationship, evidence regarding its linearity, and the lack of a $PM_{2.5}$ threshold below which deleterious health effects are not observed.

(e) Section 13.3 discusses the relationship of $PM_{2.5}$ to climate. With respect to wildfires, the *Integrated Science Assessment* describes a feedback loop in which warmer temperatures and land use change lead to more frequent wildfires, which in turn can affect precipitation patterns in ways that further increase the likelihood of fires.

(f) Section 1.5.4, within Section 1.5 "Policy Considerations," reviews the evidence regarding health effects of specific components or sources of PM, such as motor vehicle emissions, coal combustion, and vegetative burning. The authors conclude that the current state of the science does not clearly differentiate health effects resulting from exposure to different components or sources of PM; "the evidence does not indicate that any one source or component is consistently more strongly related with health effects than PM2.5 mass."

(g) Section 5.5.1 on "Biological Plausibility" describes the biological pathways by which exposure to ultrafine particles (UFP) is understood to affect human health — potentially activating not only respiratory distress but also a range of immune, nervous system, and other reactions, including oxidative stress.

(h) Section 5.5.1.1 describes the current science with respect to UFP exposure and respiratory injury, inflammation, and oxidative stress. Evidence suggests that short-term exposure to UFP is associated with markers of injury, inflammatory response, oxidative stress, and allergic asthma, which is consistent with epidemiologic evidence linking UFP exposure with asthma-related hospital admissions.

(i) Section 5.5.2.3 further investigates the connection between UFP and asthma, reviewing conclusions from the 2009 ISA as well as a more recent animal toxicological study. That study, conducted using mice, indicates that UFP penetrates into the deep lung and is associated with allergic inflammation, asthma exacerbation, and oxidative stress.

3. **Environmental Protection Agency: *Policy Assessment for PM NAAQS* 1/2020, online at https://www.epa.gov/naaqs/particulate-matter-pm-standards-policy-assessments-current-review-0**

    a. Section 3.3.2.2, Table 3-7, 3-90 (p. 190) and Table 3-8, 3-91 (p. 191)
    b. Section 3.3.3, 3-97 (p. 197)

    The U.S. Environmental Protection Agency's *Policy Assessment for Review of the PM NAAQS* is intended to serve as a bridge between science and rulemaking, interpreting the findings of the U.S. EPA *Integrated Science Assessment* with respect to existing and potential policy.

    (a) In Section 3.3.2.2., Table 3-7 compares mortality associated with $PM_{2.5}$ exposure at the current 12 µg/m^3 standard with mortality risk at potential standards of 9 µg/m^3, 10 µg/m^3, and 11 µg/m^3, and Table 3-8 calculates the number of lives that could be spared and the potential percent reduction in mortality at these lower $PM_{2.5}$ concentrations.
    (b) Section 3.3.3 summarizes the document's conclusions, stating that "the current primary $PM_{2.5}$ standards could allow a substantial number of $PM_{2.5}$-associated deaths in the U.S."

4. **U.S. Environmental Protection Agency: *Air Quality Design Values, $PM_{2.5}$ Design Values, 2019,* available online at:**
    https://www.epa.gov/air-trends/air-quality-design-values
    https://www.epa.gov/sites/production/files/2020-05/pm25_designvalues_2017_2019_final_05_26_20.xlsx

    Each year, the U.S. EPA calculates and publishes design values for each criteria pollutant for all the State, Local, and Tribal air monitoring sites in the country. Since the design values can change after the date of publication for a variety of reasons, the information in the design value tables is intended for informational use only and does not constitute a regulatory determination by U.S. EPA as whether an area has attained a NAAQS. This document shows that the 2017-2019 annual $PM_{2.5}$ design values are below the Annual $PM_{2.5}$ NAAQS at every site in the Bay Area.

5. **Bay Area Air Quality Management District: *Preliminary Analysis of $PM_{2.5}$ Values With and Without Wildfire Smoke Episodes in 2017 and 2018*, available online at https://www.baaqmd.gov/~/media/files/technical-services/pm-2-5-design-values-re-wildfires/wildfire_pm_impacts_20201006-pdf.pdf?la=en**

   This document describes the analyses performed by the Bay Area Air Quality Management District to estimate the $PM_{2.5}$ design values without days in 2017 and 2018 impacted by wildfire smoke. This preliminary analysis provides a rough evaluation of how the $PM_{2.5}$ trends would be different without the impact of a few of the largest most recent wildfires. As shown in this document, when days impacted by wildfire are excluded, the 2017-2019 $PM_{2.5}$ design values are below the applicable standards.

6. **Xiao Wu, Danielle Braun, Marianthi-Anna Kioumourtzoglou, Francesca Dominici. "Evaluating the Impact of Long-term Exposure to Fine Particulate Matter on Mortality Among the Elderly." *Science Advances*, 2020 DOI: 10.1126/sciadv.aba5692**

   Using 16 years of data for more than 68.5 million people, this study provides strong evidence of a causal link between long-term exposure to $PM_{2.5}$ concentrations below the current NAAQS and mortality. The authors estimate that an annual standard of 10 $\mu g/m^3$ would save more than 143,000 lives in one decade compared to the current 12$\mu g/m^3$ standard.

7. **Di, Q., Wang, Y., Zanobetti, A., Wang, Y., Koutrakis, P., Choirat, C., Dominici, F. and Schwartz, J.D. (2017). "Air pollution and mortality in the Medicare population." *New England Journal of Medicine*, 376(26), 2513-2522.**

   This large-scale analysis used data from the entire U.S. population over the age of 65 — approximately 61 million people — to investigate associations between mortality and exposure to ambient $PM_{2.5}$ levels as measured by U.S. EPA data, concluding that risk of death rose significantly with $PM_{2.5}$ levels at concentrations below the 12 $\mu g/m^3$ NAAQS threshold.

8. **Environmental Protection Agency: *Memorandum on Modeling Guidance for Demonstrating Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze*, 2018, available online at https://www3.epa.gov/ttn/scram/guidance/guide/O3-PM-RH-Modeling_Guidance-2018.pdf**

   This U.S. EPA document provides modeling guidance for air quality agencies charged with satisfying federal demonstration requirements. Guidance regarding calculation of PM design values acknowledges: "it is well-established that inter-annual variability in meteorological conditions often leads to year to year differences in design values, even with static emissions levels" (p. 101).

9. **Bay Area Air Quality Management District: *West Oakland Community Action Plan: Owning Our Air*, online at https://www.baaqmd.gov/community-health/community-health-protection-program/west-oakland-community-action-plan**

   This plan, shaped by a community-based steering committee, identifies specific air quality challenges in different parts of West Oakland and outlines strategies for reducing local residents' PM exposures. Chapter 5 presents a Technical Assessment that estimates the relative contributions of local and regional sources to PM concentrations, finding that proximity to local sources of PM emissions can substantially elevate exposure levels.

10. **Colmer, J., Hardman, I., Shimshack, J. and Voorheis, J., 2020. "Disparities in $PM_{2.5}$ air pollution in the United States." *Science*, 369(6503), 575-578.**

    This study combined 36 years of data across approximately 65,000 census tracts to understand disparities in $PM_{2.5}$ concentration levels. The authors found that, although both overall $PM_{2.5}$ concentration levels and differences between the most and least polluted areas have decreased, disparities in $PM_{2.5}$ concentration levels persist. More-polluted areas did not experience greater relative reductions; rather, proportional decreases have been consistent across vigintiles. The most polluted areas of 1981 remained the most polluted areas of 2016.

11. **Wettstein, Zachary S, Sumi Hoshiko, Jahan Fahimi, Robert J Harrison, Wayne E Cascio, and Ana G Rappold. 2018. "Cardiovascular and Cerebrovascular Emergency Department Visits Associated with Wildfire Smoke Exposure in California in 2015." *Journal of the American Heart Association* 7 (8). Am Heart Assoc: e007492.**

    This study examined patterns in hospital emergency department visits in the days following wildfire events across much of California, finding an increased likelihood of cardiovascular and cerebrovascular (stroke) events following nearby wildfires among people over the age of 65, particularly those with underlying cardiovascular conditions.

12. **Jones, C.G., Rappold, A.G., Vargo, J., Cascio, W.E., Kharrazi, M., McNally, B., and Hoshiko, S., 2020. "Out-of-Hospital Cardiac Arrests and Wildfire-Related Particulate Matter During 2015–2017 California Wildfires." *Journal of the American Heart Association*, 9(8), p.e014125.**

    This study examined the frequency of cardiac arrests occurring outside a medical setting (e.g. at home, work, or in a public place) in the days following wildfire events in 14 California counties. The authors found that men and women aged 35 or older were more likely to experience sudden cardiac arrest (heart attack) on days with heavy smoke, with risks appearing further elevated for people in lower income groups.

13. **California Air Resources Board: *Community Air Protection Blueprint*, online at https://ww2.arb.ca.gov/capp-blueprint**

    This state-level document outlines the process for meeting the requirements of California's AB 617 legislation mandating a statewide program to address long-standing air pollution concerns in disadvantaged communities. Designed to address the "unique needs of individual communities" (p. 7), the Blueprint calls for the development of community-specific action plans based on highly localized emissions, exposure, and public health data and guided by steering committees comprising local community members.

14. **State of California: *AB-617 Nonvehicular air pollution: criteria air pollutants and toxic air contaminants*, online at https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB617**

    This state legislation mandates a statewide program to address long-standing air pollution concerns in disadvantaged communities. California air districts in which such communities are identified are tasked with designing and deploying community-level monitoring programs and exposure reduction strategies.

15. **Environmental Protection Agency: *Our Nation's Air (2020)*, online at https://gispub.epa.gov/air/trendsreport/2020**

    This annual report from the U.S. EPA summarizes trends in air quality. In the section titled "Understanding $PM_{2.5}$ Composition Helps Reduce Fine Particle Pollution," the agency emphasizes the importance of tracking the components of secondary PM.

16. **Environmental Protection Agency: *Fine Particulate Matter National Ambient Air Quality Standards: State Implementation Plan Requirements; Final Rule*, online at https://www.govinfo.gov/content/pkg/FR-2016-08-24/pdf/2016-18768.pdf**

    a. Section B.1
    b. Section G

    This U.S. EPA document describes requirements to be met in implementing National Ambient Air Quality Standards for $PM_{2.5}$.

    (a) The agency specifies that these rules and regulations apply to "numerous and diverse sources" of harmful emissions (Section B.1, p. 58012).
    (b) Section G, "Measures to Ensure Appropriate Protections for Overburdened Populations," articulates the importance of protecting communities whose health is disproportionately impacted by $PM_{2.5}$ exposure.

17. **Achilleos, S., Kioumourtzoglou, M.-A., Wu, C.-D., Schwartz, J.D., Koutrakis, P., Papatheodorou, S.I., 2017. "Acute effects of fine particulate matter constituents on mortality: A systematic review and meta-regression analysis."** ***Environment International*** **109, 89–100.**

This meta-analysis combined data from all relevant studies investigating links between PM2.5 particle constituents and mortality through July 2015 (a total of 41 studies covering 142 cities in several world regions). The authors found evidence that exposure to the elemental carbon (EC) and potassium (K), generally recognized as traffic and wood combustion elements respectively, are each associated with increased risk of mortality. They also observed that health effects varied by region.

18. **Yang, Y., Ruan, Z., Wang, X., Yang, Y., Mason, T.G., Lin, H., Tian, L., 2019. "Short-term and long-term exposures to fine particulate matter constituents and health: A systematic review and meta-analysis."** ***Environmental Pollution*** **247, 874–882.**

This meta-analysis reviewed all relevant studies through August 2018 examining mortality and morbidity in relation to exposure to different components of PM. The authors found consistent associations between cardiovascular morbidity and mortality and exposure to black carbon and organic carbon (associated with a range of combustion including motor vehicle emissions and biomass burning). They also found likely associations between cardiovascular health effects and exposure to PM2.5 nitrate, sulfate, zinc, silicon, iron, nickel, vanadium, and potassium; and likely associations between respiratory health effects and exposure to PM2.5 nitrate, sulfate, and vanadium.

19. **Ohlwein, S., Kappeler, R., Joss, M.K., Künzli, N., Hoffmann, B., 2019. "Health effects of ultrafine particles: A systematic literature review update of epidemiological evidence."** ***International Journal of Public Health*** **64, 547–559.**

This meta-analysis reviewed 85 recent studies (published 2011 through 2017) of the health effects of ultrafine particles (UFP) in ambient air pollution. The authors found some evidence for increased risk of short-term inflammatory and cardiovascular effects with UFP exposure beyond the expected effects of larger categories of PM.

20. **Independent Particulate Matter Review Panel:** ***Final letter to Administrator Wheeler with the IPMRP's recommendations*****, October 22, 2019. Available online at https://www.ucsusa.org/meeting-independent-particulate-matter-review-panel**

This letter, written by the scientists who made up the U.S. EPA's Clean Air Scientific Advisory Committee (CASAC) before it was dismissed without notice in 2018, contains these experts' findings after reviewing the EPA's Integrated Science Assessment (ISA, Reference 2) and Policy Assessment (PA, Reference 3) regarding particulate matter. The panel strongly called for stricter PM standards based on the evidence in the ISA and PA.

Particulate Matter:
Spotlight on Health Protection

Appendix B: Summary of Advisory Council Deliberations

APPENDIX B: ADVISORY COUNCIL MEETING OF JULY 31, 2020 SUMMARY OF DELIBERATIONS

The Bay Area Air Quality Management District (Air District) Advisory Council meeting of July 31, 2020, concluded with the Advisory Council's discussion of three sets of messages regarding particulate matter. The first set, "Particulate Matter Reduction Statements," reflects the Advisory Council's findings upon review of the presentations and public comments received during the PM Symposium Series. The second set, "Framework," reflects the Advisory Council's suggested guiding principles for PM projects and rule development. The third set, "Recommended Actions," contains specific recommended priorities for Air District action. When finalized, the Statements, Framework, and Recommended Actions will be submitted to the Executive Board as Advisory Council recommendations.

Chair Stan Hayes, who composed a preliminary draft of the document, presented the Statements, Framework, and Recommended Actions to the Advisory Council members. He explained that the document was intended to reflect sentiments expressed by Advisory Council members in prior PM deliberations. By drafting these items, he hoped to provide a starting point for discussion.

The ensuing deliberations, led by Chair Hayes, focused on each individual entry under the "Statements" and "Framework" headings. (Due to time constraints, discussion of "Recommended Actions" was reserved for the next Advisory Council meeting.) Some items were immediately approved by Advisory Council members as written in the preliminary draft; others led to discussion and revision. This summary provides a high-level recap of those discussions.

PARTICULATE MATTER REDUCTION STATEMENTS DISCUSSION

After establishing the need to reorder the Particulate Matter Reduction Statements for greater clarity, the Advisory Council considered each item individually.

Particulate Matter Reduction Statements Approved

The following Particulate Matter Reduction Statements were approved without significant changes.

The current PM NAAQS are not sufficiently health protective.

PM is the health risk driver in Bay Area air, both $PM_{2.5}$ as a criteria pollutant and diesel PM as a toxic air contaminant.

There is no evidence of a health effects $PM_{2.5}$ threshold; thus, additional PM reductions beyond the current standards will achieve additional public health improvement.

More stringent standards are needed and would save thousands of lives in the U.S. each year.

*Some PM localized hot-spot areas experience PM levels significantly higher than their community-average level.**

*The qualifier "may" was removed from this statement, which previously contained the phrase "may experience."

Particulate Matter Reduction Statements for Revision

Three Particulate Matter Reduction Statements related to attainment of potential $PM_{2.5}$ standards or targets were discussed at greater length:

Excluding wildfire smoke days as exceptional events, the Bay Area has attained the current federal annual/24-hour (12/35 µg/m^3) $PM_{2.5}$ national ambient air quality standards (NAAQS).

The Bay Area also would attain alternative, more stringent 10/25 µg/m^3 $PM_{2.5}$ NAAQS (except for West Oakland, whose annual average $PM_{2.5}$ in 2018 was above an alternative 10 µg/m^3 standard by 0.7 µg/m^3, or 7%).

An Air District guideline "target" below the current $PM_{2.5}$ NAAQS is warranted; to be effective, it would need to be at or below an annual average of 10 µg/m^3.

To explain the rationale for these Particulate Matter Reduction Statements, Chair Hayes presented graphs of Bay Area design values for each three-year period from 2005 through 2018. Design values are calculations of average concentration levels; the annual design value is the three-year average of the highest maximum $PM_{2.5}$ concentrations measured in the area, and the 24-hour design value is the three-year average of the 98th percentile of the daily maximum $PM_{2.5}$ concentration in the area. Chair Hayes used design value data provided by the Air District from each of its 16 monitoring stations to create the graphs, excluding wildfire events.

Based on the Air District's calculations, Chair Hayes recognized that the Bay Area has in recent years attained the current federal annual 12 µg/m^3 standard at all monitoring locations (**Figure 1**). If targets were set at 10 µg/m^3, recent measurements indicate that air quality near the monitoring stations in West Oakland and Laney College would not meet the 10 µg/m^3 target. If targets were set at 8 µg/m^3, these historical data suggest that nearly all monitoring stations would register Bay Area air quality that would not meet the 8 µg/m^3 target.

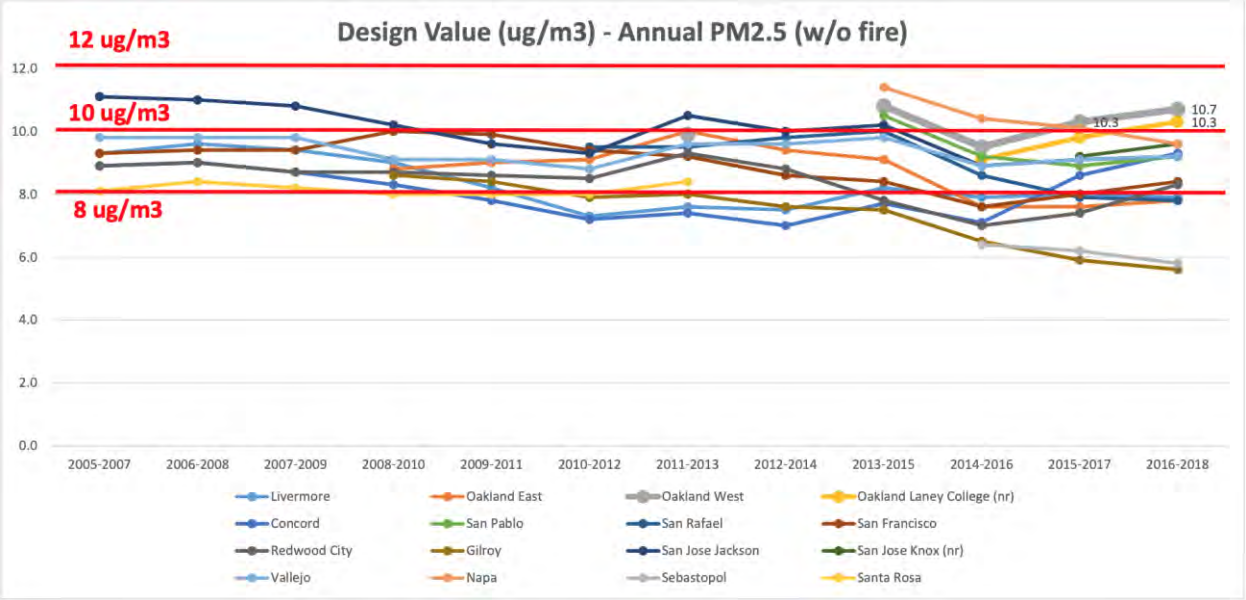

Figure 1 - Estimated annual design values for 16 Air District monitoring stations, 2005-2018

For the 24-hr design values, the Bay Area has been in attainment with the current standard of 35 µg/m^3 for the past decade (**Figure 2**). If targets were set at the more stringent standard of 25 µg/m^3, the most recent data indicate Bay Area air quality would have attained (or in West Oakland and San Jose come very close to attaining) this target.

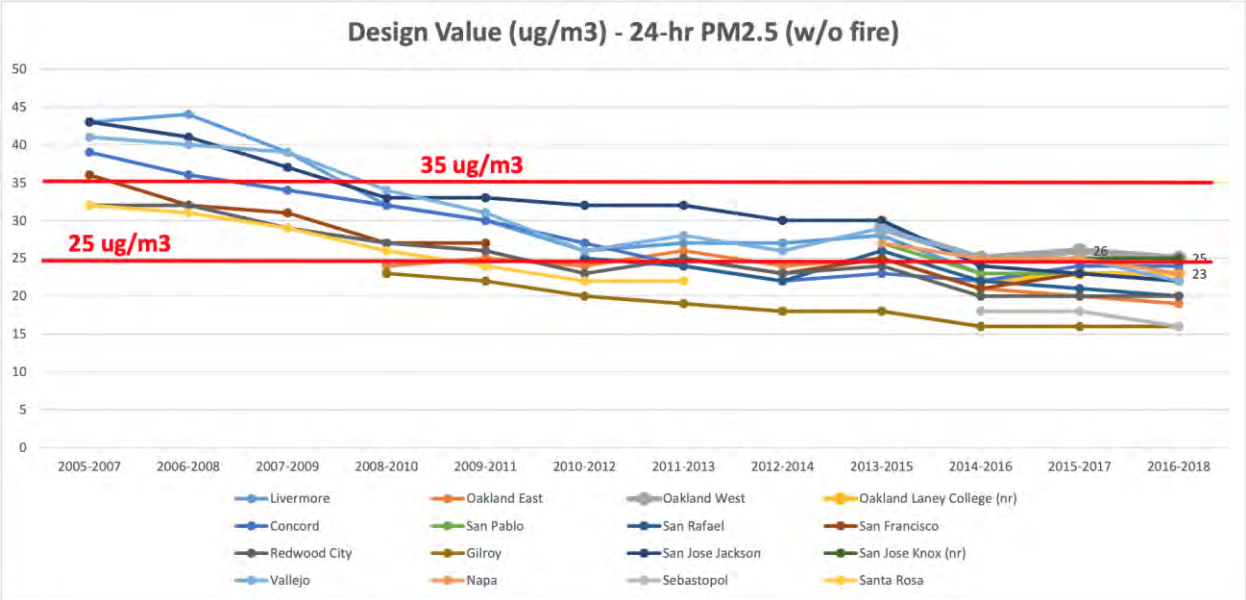

Figure 2 - Estimated 24-hr design values for 16 Air District monitoring stations, 2005-2018

Discussion centered on the following topics:

Wildfire. Advisory Council members acknowledged that if wildfire data were included, design values based on monitoring data would show $PM_{2.5}$ concentrations in excess of the current federal annual standard of 12 µg/m^3 and the current federal 24-hr standard of 35 µg/m^3.

Localized hot-spots. Although Air District data provided some indication of the differences in air quality across the region by showing separate design values for each monitoring station, Advisory Council members acknowledged that $PM_{2.5}$ concentrations may be higher in specific neighborhoods.

Achieving 8 µg/m^3 vs 10 µg/m^3. Acknowledging that the data and conclusions presented to the Advisory Council throughout the PM Symposium Series indicate meeting more stringent targets would achieve greater health protection, Advisory Council members determined that the statements should reflect the possibility of setting an annual target at 8 µg/m^3.

Bright-line standard vs linear dose-response model. Recognizing that there appears to be a linear dose-response relationship between $PM_{2.5}$ exposure and health effects, Advisory Council members discussed whether it was appropriate to set specific targets (such as annual design values of 8 µg/m^3 or 10 µg/m^3) rather than considering air quality objectives in reference to a no-threshold, linear dose-response. An alternative approach was proposed to evaluate potential projects by using health impact models (e.g., projected shifts in emergency department visits, deaths, missed work or school days) to estimate costs or benefits of a change in $PM_{2.5}$ concentration resulting from each project.

REVISIONS

The Advisory Council made the following determinations regarding revision of the three Particulate Matter Reduction Statements:

Statement:

Excluding wildfire smoke days as exceptional events, the Bay Area has attained the current federal annual/24-hour (12/35 µg/m^3) $PM_{2.5}$ national ambient air quality standards (NAAQS).

Revision: Clarify that the Particulate Matter Reduction Statement refers to the Bay Area as a whole and that localized hot-spots may exceed these standards.

Statement:

The Bay Area also would attain alternative, more stringent 10/25 µg/m^3 $PM_{2.5}$ NAAQS (except for West Oakland, whose annual average $PM_{2.5}$ in 2018 was above an alternative 10 µg/m^3 standard by 0.7 µg/m^3, or 7%).

Revision: Amend the statement to also reflect Bay Area $PM_{2.5}$ concentration levels relative to a potential annual target of 8 µg/m^3.

Statement:

An Air District guideline "target" below the current $PM_{2.5}$ NAAQS is warranted; to be effective, it would need to be at or below an annual average of 10 µg/m^3.

Revision: Reword the statement to reflect, based on the Air District's design-value data Chair Hayes presented, that keeping annual $PM_{2.5}$ concentrations at or below 10 µg/m^3 would save additional lives. Advisory Council members also discussed the possibility of amending the statement to reflect the absence of a $PM_{2.5}$ threshold for health impacts and indicate that, accordingly, the goal of the Air District should be to achieve the lowest $PM_{2.5}$ concentrations possible.

FRAMEWORK DISCUSSION

Framework Items Approved

The following Framework items were approved without significant changes.

The most effective PM reduction measures may differ across communities, due to varying source mix and size, ambient PM concentration levels, physical circumstances (e.g., meteorology, terrain), and other relevant factors.

The Air District should focus PM reduction in areas with increased exposure, health vulnerability, and the areas with increased impacts and sensitive populations (e.g., children, nonwhite, low socioeconomic status, elderly).

PM measures should consider regional (Bay Area-wide), local (community-level), and localized hot-spot (block-level) sources.

*PM reduction strategies will need to address multiple source categories.**

* This statement was amended to remove a second clause that was deemed unnecessary. The second clause read: "there is no 'silver bullet,' rather, it is more like 'silver buckshot.'"

Framework Items for Revision

The Advisory Council made the following determinations regarding revision of three Framework items:

Framework Item:

Where the air district has authority, take maximal action.

Revision: Reflect the urgency of the problem and the feasibility of potential solutions. Language proposed during the meeting read: "move quickly to take maximal feasible action."

Framework Item:

Lower-income populations with higher long-term PM exposure are more susceptible to COVID-19, due to such factors as lesser ability to work from home, denser housing situations (e.g., congregate, multi-family), and poorer access to medical care.

Revision: Three possibilities were proposed for later consideration:

Delete this item, as its purpose is already reflected in the Framework item calling for Air District efforts to focus on populations at greater risk.

Substitute more general language, e.g.: "The emergence of the COVID-19 pandemic makes the attention to particulate matter even more urgent."

Add more specific language to describe the multiple ways that PM exposure and COVID-19 interact to increase health risk for vulnerable populations (e.g., each can cause or exacerbate health conditions that increase susceptibility to the other; both are associated with racial disparities; PM exposure may directly lead to increased health risk from COVID-19).

Framework Item:

PM reduction strategies should consider emission reduction measures for both primary PM and secondary PM formed in the air by photochemical processes (i.e., emissions of precursor ROG, NOx, NH_3, and SO_2).

Revision: A slight change was made to acknowledge secondary PM formation processes that are not photochemical. The revised version reads: *PM reduction strategies should consider emission reduction measures for both primary PM and secondary PM formed in the air (e.g., emissions of precursor ROG, NOx, NH_3, and SO_2).*

NEXT STEPS

Due to time constraints, the Advisory Council determined that the "Recommended Actions" would be discussed at the next Advisory Council meeting, scheduled for October 9. Further revisions to the Statements and Framework are also expected to be discussed at that meeting.

APPENDIX B: ADVISORY COUNCIL MEETING OF OCT. 9, 2020 SUMMARY OF DELIBERATIONS

Continuing a discussion that began during its July 31 meeting, the October 9 meeting of the Bay Area Air Quality Management District Advisory Council centered on three sets of messages regarding particulate matter. The first set, "Particulate Matter Reduction Statements," reflects the Advisory Council's findings upon review of the presentations and public comments received during the PM Symposium Series. The second set, "Framework," reflects the Advisory Council's suggested guiding principles for PM projects and rule development. The third set, "Recommended Actions," contains specific recommended priorities for Air District action. When finalized, the Particulate Matter Reduction Statements, Framework, and Recommended Actions will be submitted to the Executive Committee of the Air District Board of Directors as Advisory Council recommendations.

During its previous meeting on July 31, the Advisory Council made suggestions for reordering and revising some of the Particulate Matter Reduction Statements and Framework items. The first focus for deliberation at the October 9 meeting was to review these changes and updates. The Advisory Council then turned to the Recommended Actions. Time constraints limited the discussion to a subset of those items.

This summary provides a high-level synthesis of these discussions, beginning by describing the broad issues raised relevant to all three types of messages, and proceeding to Advisory Council members' more focused critiques of the Particulate Matter Reduction Statements, Framework, and Recommended Actions respectively. A full and sequential record of these discussions is available on the Air District website, as noted in Appendix D.

OVERARCHING TOPICS FOR ADVISORY COUNCIL RECOMMENDATIONS

A number of broad topics were raised by the Advisory Council members and Air District Board of Directors Chair Rod Sinks relevant to the Advisory Council's recommendations as a whole: the limits of the Air District's authority with respect to setting air quality standards; the value of recommending a "bright-line" target for PM concentration levels versus a dose-response framework; the importance of addressing wildfire contributions to PM exposure; the Board's desire for guidance on approaches to decision making; and presentation considerations including source citations and organizing items as discrete, stand-alone statements versus logically structured arguments.

Standards and Air District authority

Advisory Council members requested clarification on the Air District's authority with respect to setting air quality standards and the distinction between a "standard" and a "target." Air District Counsel Brian Bunger clarified that standard-setting is done at the federal and state

levels, whereas attainment of those standards is the responsibility of the Air District. However, the Air District has the authority to set targets that are stricter than these standards and to develop rules and regulations designed to achieve such targets. Furthermore, the Air District has broad latitude to regulate toxic air contaminants, which include diesel PM. If other species of PM were to be designated as toxic air contaminants, they would be covered under Air District rules including 11-18 (Reduction of risk from air toxic emissions at existing facilities) and 2-5 (New source review of toxic air contaminants).

Recommending a bright-line target vs dose-response model

Several Advisory Council members voiced support for explicitly recommending that the Air District set a $PM_{2.5}$ annual target consistent with the Advisory Council's findings. Based on the U.S. EPA's most recent Integrated Science Assessment (ISA) and Policy Assessment (PA) concerning PM, as well as review of these documents by the Independent Particulate Matter Review Panel of expert scientists, this target could be justified at a level from 10 $\mu g/m^3$ to as low as 8 $\mu g/m^3$.

Concern was raised that a "bright-line" target may not be consistent with the Advisory Council's findings (based on the evidence presented in the U.S. EPA ISA) regarding an apparently linear, no-threshold dose-response relationship between $PM_{2.5}$ exposure and health effects. As in the July 31 Advisory Council meeting, it was proposed the Advisory Council consider instead approaching $PM_{2.5}$ in the same manner as carcinogens, pursuing reduction efforts analogous to controls on toxic substances such as lead, and perhaps using metrics such as hospital emergency department visits.

Accounting for wildfire contributions to PM exposure

Although wildfires have historically been treated as "exceptional events" rather than integrated into most analyses of air quality progress, several Advisory Council members expressed that the increasing duration and intensity of wildfires in the Bay Area have made this designation inaccurate: wildfires can no longer be regarded as rare occurrences. With wildfires expected to continue worsening due to climate change, Advisory Council members argued for explicitly acknowledging this trend, incorporating wildfire exposure into $PM_{2.5}$ exposure models, and making wildfire mitigation and management efforts a priority for the Air District.

Acute risks from short-term exposure to wildfire smoke were emphasized in addition to the contribution of wildfire days to annual concentration averages. For example, if the Air District were to set and meet the equivalent of an annual target of 8 $\mu g/m^3$ for the region, wildfires resulting in 30 days of exposure to 150 $\mu g/m^3$ would bring the annual average up to 20 $\mu g/m^3$, well beyond even the federal standard of 12 $\mu g/m^3$. Board Chair Sinks shared that the Air District has obtained a small amount of funding from the State of California to establish "clean air centers" in which vulnerable populations in communities heavily impacted by wildfires can shelter during wildfire outbreaks.

Providing the Board of Directors with guidance for decision making

Board Chair Sinks expressed his hope that the Advisory Council's recommendations would provide guidance on how to evaluate different options for pursuing PM exposure reductions. He shared the example of the October 1 Stationary Source Committee meeting, in which two different types of emissions controls were considered for Fluidized Catalytic Cracking Units (which convert crude oil into petroleum products such as gasoline). He stated that the Board would benefit from the Advisory Council's advice on how to compare the more stringent control model with its more cost-effective alternative in light of numerous potential impacts including health and economic considerations. To support this and other PM reduction decisions, he encouraged the Advisory Council to provide the Board with tools for evaluating such trade-offs.

Presentation of the Advisory Council's recommendations

The ordering of items in the Particulate Matter Reduction Statements, Framework, and Recommended Actions was a topic of discussion. The question arose of whether to treat each entry as a discrete, stand-alone item or to instead ensure they are written and organized in such a way that they build on one another in the manner of a logical argument. An additional suggestion was to link Particulate Matter Reduction Statements to corresponding Framework items and Recommended Actions.

Another presentation concern was ensuring key scientific sources (such as the U.S. EPA ISA) are referenced in findings that rely on the evidence provided by those sources. Chair Stan Hayes shared that the Air District team is preparing an annotated bibliography for the Statements and Framework intended to supply these references.

PARTICULATE MATTER REDUCTION STATEMENTS DISCUSSION

Particulate Matter Reduction Statements Approved:

Advisory Council members agreed on the wording of two of the Particulate Matter Reduction Statements as they were presented during the meeting:

***PMRS1**) PM is the health risk driver in Bay Area air, both $PM_{2.5}$ as a criteria pollutant and diesel PM as a toxic air contaminant.*

***PMRS9**) Although a large fraction of $PM_{2.5}$ is regionally contributed, substantially elevated $PM_{2.5}$ exposures can occur in locations adjacent to local PM sources.*

Particulate Matter Reduction Statements for Revision:

Advisory Council members raised concerns and made suggestions for revising eight Particulate Matter Reduction Statements. These discussion points are summarized beneath each Particulate Matter Reduction Statement.

PMRS2*) The current PM national ambient air quality standards (NAAQS) are not sufficiently health protective.*

- Concern was raised over the use of the term "sufficient" in this statement, as it was viewed as necessitating precise delineation of an acceptable level of health protection. A proposal was made to instead express the need for "improvements" in PM targets and health protection.

PMRS3*) More stringent standards are needed and would save thousands of lives in the U.S. and many Bay Area lives each year.*

- An insertion was made to clarify that more stringent standards, "*if met*," would save lives.

- Concern was raised over the lack of quantification regarding mortality or morbidity.

- It was noted that this Particulate Matter Reduction Statement and PMRS6 may duplicate one another.

PMRS4*) There is no evidence of a health effects* $PM_{2.5}$ *threshold; thus, it follows that additional PM reductions beyond the current standards will achieve additional public health benefits.*

- Discussion of this statement centered on the nature of the concentration-response relationship and whether the absence of a health effects threshold necessarily justifies a more stringent target. A potential counterargument was presented that effects could theoretically *approach* zero below a certain threshold without ever reaching zero (i.e. there could be an asymptote). Advisory Council members clarified that the U.S. EPA ISA demonstrates that evidence points to a linear or near-linear concentration-response relationship between PM exposure and health effects.

- The Particulate Matter Reduction Statement was marked for revision. A preliminary revision was drafted to read: *"There is no known safe level of exposure to* $PM_{2.5}$*, thus it follows that additional PM reductions beyond the current standards will achieve additional public health benefits."*

PMRS5*) With the exception of data affected by wildfire emissions, PM concentrations in the Bay Area region would be at or below existing applicable state and federal ambient air quality standards.*

- As discussed in Section 1 above, the Advisory Council agreed that the current and projected frequency, duration, and intensity of California wildfires require approaching them as non-exceptional events.

- A proposal was made to consider setting air quality targets at a level that, when averaged with days affected by wildfire, would result in a health protective annual average.

- The appropriateness of stating the Bay Area region meets existing standards was questioned due to the Advisory Council having found those standards inadequate and to the concern that some hot-spot areas experiencing higher $PM_{2.5}$ concentration levels have not historically been captured by the Air District's monitoring network.

- The Particulate Matter Reduction Statement was marked for revision. A preliminary revision was drafted to read: *"The Bay Area has made substantial progress at reducing regional $PM_{2.5}$ levels to meet current $PM_{2.5}$ standards, however, 1) exposures vary substantially across communities; 2) wildfire smoke increases exposures substantially above standards; and 3) more stringent standards would be more health protective."*

PMRS6*) With additional PM emission reductions, the Bay Area region could also make progress toward more stringent alternate standards providing an additional public health benefit to communities.*

- The word "alternate" was removed from the Particulate Matter Reduction Statement.

- The Particulate Matter Reduction Statement was marked for revision.

PMRS7*) Allowance should be made for year-to-year variability in meteorological and other weather-related factors that cause PM concentrations to vary, even if emissions and other conditions were to remain unchanged.*

- Advisory Council members expressed confusion regarding the purpose of this Particulate Matter Reduction Statement and the term "allowance."

- The Particulate Matter Reduction Statement was marked for revision.

PMRS8*) An Air District guideline "target" below the current $PM_{2.5}$ NAAQS may be warranted; if the Air District were to set that target at an annual average of 10 µg/m^3 to as low as 8 µg/m^3, national data supports that it would save additional lives.*

- Advisory Council members expressed concern that setting targets for the region fails to address problems of equity and heterogeneity: some people in the Bay Area are more vulnerable to harm from $PM_{2.5}$ and some areas experience higher $PM_{2.5}$ concentrations.

- Advisory Council members also requested that the source for the specific concentration targets (the U.S. EPA ISA) be referenced.

- The Particulate Matter Reduction Statement was marked for revision.

- Later in the meeting, during the discussion of Recommended Actions, Advisory Council members returned to the topic of impact metrics such as specifying how many lives would be saved if a more stringent target was met. (The research the U.S. EPA used to quantify morbidity did not include the Bay Area.)

***PMRS10**) Wildfire PM is a serious contributor to PM health effects; early health studies are of concern; more research on acute and sub-chronic effects is ongoing and urgently needed.*

- Advisory Council members emphasized the need to treat wildfire PM exposure as an urgent problem that the Air District must address.

- Advisory Council members expressed the importance of both "acute" risks from wildfire smoke exposure as well as "chronic" risks of ongoing exposure to $PM_{2.5}$ from other sources.

- The following addition was made to the Particulate Matter Reduction Statement: *"Wildfire PM exposure is projected to increase in duration and intensity, due to climate change."*

FRAMEWORK DISCUSSION

There was general agreement among Advisory Council members on most of the Framework items. The following suggestions were made:

- Specify scientific evidence for designation of vulnerable groups. A preliminary revision was made to *F3* to clarify which subpopulations the U.S. EPA ISA identifies as disproportionately vulnerable to $PM_{2.5}$ health risks.

- Reorder to move to the top the following items related to health equity and exposure heterogeneity:

F3) *The Air District should focus PM reduction in areas with increased exposure, health vulnerability, and those areas with increased impacts and sensitive populations (e.g., U.S. EPA identifies children, nonwhite, low socioeconomic status, elderly).*

F7*) PM reduction strategies should prioritize those measures that are most effective in reducing exposure and improving public health and health equity in the most impacted areas.*

F2*) The most effective exposure reduction measures may differ across communities, due to varying source mix and size, ambient PM concentration levels, physical circumstances (e.g., meteorology, terrain), and other relevant factors.*

RECOMMENDED ACTIONS DISCUSSION

The discussion of Recommended Actions included general considerations of prioritization and scope in addition to the suggestion of a new Recommended Action to set a $PM_{2.5}$ target.

Air District authority vs advocacy. A general discussion topic concerning Recommended Actions was whether to prioritize actions under the control of the Air District rather than advocacy activities intended to influence state and federal governing bodies. The Advisory Council discussed the possibility of organizing recommendations into separate categories for a) direct actions available to the Air District and b) advocacy actions directed toward other authorities.

Staffing is outside Advisory Council's scope. A number of the draft Recommended Actions concerned increases in staff. The Advisory Council determined that it was beyond its scope to make recommendations regarding the Air District's management and allocation of human resources.

Setting a specific $PM_{2.5}$ target. Several Advisory Council members called for adding a Recommended Action that the Air District set a $PM_{2.5}$ annual target consistent with the Particulate Matter Reduction Statements.

Discussion of individual Recommended Actions

RA1*) Make air quality data more accessible and closer to real time.*

- Air District staff clarified that while a goal is to make data available as quickly as possible (currently posted every 20 minutes), quality control, quality assurance, and sample analysis measures make "real time" accessibility unfeasible.

- The Recommended Action was revised to read: *"Continue working to make air quality data more accessible and timely."*

***RA2**) Some species of PM may be more dangerous than others; as yet, no PM species can be exonerated; better PM speciation is needed, along with more monitoring.*

- Air District staff clarified that, although the Air District will continue to expand its PM speciation measurement efforts, in order to drive policy, it is necessary to conduct health research at a national scale, which is beyond the Air District's capacity.

- The Recommended Action was revised to read: *"Some species of PM may be more dangerous than others; as yet, no PM species can be exonerated. Make current PM speciation data more available. Advocate for the U.S. EPA national monitoring guidance and requirements to increase PM speciation."*

***RA3**) Monitoring and other studies for UFP are important and should be continued and expanded; further studies linking UFP and health impacts are needed.*

- Air District staff clarified that the Air District will continue its UFP measurements and evaluate whether changes of the measurement network are warranted. However, in order to drive policy, it is necessary to conduct health research at a national scale, which is beyond the capacity of the Air District.

- The Recommended Action was revised to read: *"Advocate for increased, broader, national monitoring and studies of UFP; support further national studies on the health impacts of UFP."*

***RA4**) Set improved UFP filtration requirements for on-road vehicles.*

- Regulation of mobile sources is outside the Air District's authority.

- The Recommended Action was revised to read: *"Advocate for appropriate federal and state agencies to set improved UFP filtration requirements for on-road vehicles."*

***RA5**) Increase staff for enforcement and accidental release events.*
***RA6**) Increase staff to implement/enforce Rule 11-18.*
***RA7**) Devote more staff to risk assessment for air toxics programs like Rule 11-18.*

- Advisory Council members expressed that it is beyond the Advisory Council's scope to make specific recommendations regarding the Air District's management of human resources.

- The three Recommended Actions were revised into one: *"Strengthen implementation and enforcement of programs and rules intended to reduce exposures to $PM_{2.5}$ (including diesel PM) and seek sufficient resources to do so."*

***RA8**) Improve emission estimation methods for emerging source categories (e.g., tires and brakes, road dust).*

- Air District staff clarified that the California Air Resources Board (CARB) is currently working on improving estimation methods for brake and tire wear and road dust; while the Air District has the authority to conduct its own research, partnering with CARB would avoid duplicating these efforts and would be a more efficient use of resources. Additionally, the Air District has established that reduction of vehicle miles traveled (VMT) is a priority regarding on-road mobile-source emissions.

- The Recommended Action was revised to read: *"Advocate for improved emission estimation and control methods for emerging source categories (e.g., tires and brakes, road dust)."*

***RA9**) Develop Air District PM action plans for individual highly impacted communities.*

- Advisory Council members suggested adding the term "strategic" to "action plans" and linking these plans to specific PM reduction targets.

- The Recommended Action was revised to read: *"Develop Air District PM strategic action plans for individual highly impacted communities with appropriate targets."*

***RA10**) Further develop and implement health protective measures for the community during wildfires.*

- Advisory Council members suggested adding the terms "strategy" and "guidance."

- The Recommended Action was revised to read: *"Further develop and implement a strategy of health protective measures and guidance for the community during wildfire episodes."*

***RA11**) Encourage telework.*

- Advisory Council members expressed that the goal of encouraging telework is to reduce VMT, and telework is not available to everyone; the Advisory Council's recommendations should therefore support a range of strategies, including telework, that reduce VMT.

- The Recommended Action was revised to read: *"Implement and encourage strategies to reduce vehicle miles traveled (e.g., active transportation, public transit, telework where possible, and land use planning)."*

***RA12**) Conduct community-level health exposure assessments.*

- Advisory Council members raised the possibility of specifically referencing California's AB 617, which mandates a statewide program to address long-standing air pollution concerns in disadvantaged communities. Air District staff expressed their intention that ongoing localized health impact assessment efforts, in addition to satisfying AB 617, also go beyond these state-level requirements.

- The Recommended Action was revised to read: *"Expand community-level exposure and health impact assessments."*

***RA13**) Expand existing rule limiting visible emissions and trackout (Rules 6-1, 6-6) to address communities that are overburdened or experience continuous construction.*

- Air District staff expressed a preference for broader language not limiting recommendations to specific rules.

- The Recommended Action was revised to read: *"Evaluate improvements to existing rules limiting visible emissions and trackout of road dust to address communities that are overburdened."*

***RA14**) Modify permitting regulations to address hyper-localized health risks.*

- The Recommended Action was revised to insert the word "hot-spot" before "health risks."

***RA15**) Adopt rule requiring that woodburning devices be disabled or replaced when properties are sold.*

- Advisory Council members discussed the possibility of expanding the recommendation to include home renovations as well as sales.

- Concerns were raised regarding burdens on homeowners, the possibility of such a rule leading to more people making changes to their homes without seeking permits, and the potential for gas fireplaces to be used as replacements, which would introduce other air quality problems.

- The Recommended Action was marked for revision.

***RA16**) Adopt rule to improve the efficiency of water heaters and space heaters.*

- Air District staff clarified that the relevant concern is emission of nitrogen oxides (NOx), which leads to the formation of ammonium nitrate (a form of particulate matter).

- Advisory Council members discussed clarifying the goal of electrification.
- The Recommended Action was marked for revision.

NEXT STEPS

Due to time constraints, the Advisory Council determined that it would discuss the remaining Recommended Actions at the next Advisory Council meeting, scheduled for November 9. Advisory Council members were asked to submit any further comments on the Particulate Matter Reduction Statements, Framework items, and Recommended Actions to Air District staff by October 16. The plan was established for Air District staff to compile these comments, without attribution, and include them in the publicly available materials for the November 9 meeting.

APPENDIX B: ADVISORY COUNCIL MEETING OF NOV. 9, 2020 SUMMARY OF DELIBERATIONS

Continuing discussions from its July 31 and October 9 meetings, the Advisory Council centered its November 9, 2020 meeting on three sets of messages regarding particulate matter. The first set, "Particulate Matter Reduction Statements," reflects the Advisory Council's findings upon review of the presentations and public comments received during the PM Symposium Series. The second set, "Framework," reflects the Advisory Council's suggested guiding principles for PM projects and rule development. The third set, "Recommended Actions," contains specific recommended priorities for Air District action. When finalized, the Particulate Matter Reduction Statements, Framework, and Recommended Actions will be submitted to the Board of Directors.

After discussing each item in each set of messages, the Advisory Council identified a need to reorganize the Recommended Actions into topical categories reflecting key messages of the Particulate Matter Reduction Statements and Framework. A revised draft of the Recommended Actions will be prepared by a subcommittee of the Advisory Council and discussed at an additional Advisory Council meeting to take place before the Advisory Council's December 16 meeting with the Board of Directors.

This summary recaps the Advisory Council's discussion of the Particulate Matter Reduction Statements, Framework, and Recommended Actions, indicating which items were approved without substantive revision and providing brief descriptions of discussion points for those that were substantively revised. An introductory section briefly summarizes topics of discussion that arose during deliberations and have relevance to all three sets of messages, and a final section reflects input from public comment.

For a full and sequential record of the November 9 meeting, please see the video recording available at http://baha.granicus.com/MediaPlayer.php?clip_id=7783.

OVERARCHING TOPICS FOR ADVISORY COUNCIL RECOMMENDATIONS

A number of broad topics arose during deliberations: the inclusion of 10 $\mu g/m^3$ as a potentially viable target for annual average $PM_{2.5}$ concentration levels, the public health cost effectiveness of focusing on "controllable" sources of PM emissions versus mitigation measures for wildfire PM exposures, the relevance of climate impacts in determining PM reduction measures, and the practical value of obtaining authority for the Air District to set air quality "standards" rather than "target values."

Including 10 µg/m^3 as a viable target

Some Advisory Council members, and public commenters, objected to including 10 µg/m^3 as a potentially viable target for annual average $PM_{2.5}$ concentration levels, arguing that the scientific findings presented during the PM Symposium Series justified a target of 8 µg/m^3. Other Advisory Council members were in favor of keeping an upper limit of 10 µg/m^3 in the recommendations, regarding the language of "10 µg/m^3 to as low as 8 µg/m^3" as most consistent with the findings of the U.S. EPA PM Policy Assessment and the Independent Particulate Matter Review Panel.

Relative influence of "controllable" sources

Concern was voiced about the public health cost-effectiveness of focusing on local anthropogenic sources whose PM contributions are "swamped" by that of wildfires. Questions were raised as to whether the cost of reducing "controllable" Bay Area emissions could be justified if these air quality improvements would be dwarfed by "uncontrollable" factors, and whether instead allocating those resources to indoor air purification and other wildfire responses would have a greater positive impact on public health.

Climate co-benefits

An argument raised in favor of investing in controlling emissions from local and regional sources was that doing so would also reduce greenhouse gases, which contribute to the dire public health problem of climate change. A counterargument was made that the Advisory Council is currently tasked with identifying means of reducing health impacts from particulate matter, not greenhouse gases, and that the complicated interplay between air pollution levels and climate change can mean that measures to improve one set of conditions effectively worsen the other.

Acquiring Air District authority to establish a standard

The prospect of seeking legislative authority for the Air District to set official air quality standards (which are currently set by state and federal authorities) was discussed at several points during the meeting. Some Advisory Council members, as well as representatives from community organizations speaking during public comment, expressed support for this strategy. Air District Legal Counsel stated that such a change would not add to the Air District's capacity to monitor and improve air quality and that specifying a "target" for PM concentration levels would fully enable the Air District to exercise its authority to meet that target.

PARTICULATE MATTER REDUCTION STATEMENTS DISCUSSION

Particulate Matter Reduction Statements Approved:

Advisory Council members agreed on the following Particulate Matter Reduction Statements. Minor revisions for clarity were made to some items, as indicated.

PMRS1*) Particulate Matter (PM) is an important health risk driver in Bay Area air, both $PM_{2.5}$ as a criteria pollutant and diesel PM as a toxic air contaminant.*

PMRS2*) The Bay Area has made substantial progress at reducing regional $PM_{2.5}$ levels to meet current $PM_{2.5}$ standards; however, 1) more stringent standards would be more health protective; 2) exposures vary substantially across communities; and 3) wildfire smoke increases $PM_{2.5}$ levels substantially above standards.*

- The phrase "increases $PM_{2.5}$ levels" replaced earlier wording of "increases exposure."

PMRS3) *The current particulate matter national ambient air quality standards (NAAQS) are not health protective.*

The Advisory Council concurs with the following statement: "Based on scientific evidence, as detailed in Attachment B [of our letter], the [Independent Particulate Matter Review Panel] finds that the current suite of primary fine particle ($PM_{2.5}$) annual and 24-hour standards are not protective of public health. Both of these standards should be revised to new levels, while retaining their current indicators, averaging times, and forms. The annual standard should be revised to a range of 10 µg/m^3 to 8 µg/m^3. The 24-hour standard should be revised to a range of 30 µg/m^3 to 25 µg/m^3. These scientific findings are based on consistent epidemiological evidence from multiple multi-city studies, augmented with evidence from single-city studies, at policy-relevant ambient concentrations in areas with design values at and below the levels of the current standards, and are supported by research from experimental models in animals and humans and by accountability studies." (Independent Particulate Review Panel letter on Draft EPA PM Policy Assessment, October 2019).

PMRS4*) More stringent standards to reduce exposures are needed and, if met, would save thousands of lives in the U.S. and many Bay Area lives each year.*

- The phrase "to reduce exposures" was added to the statement.

PMRS5) *There is no known threshold for harmful $PM_{2.5}$ health effects, thus is follows that additional reductions of $PM_{2.5}$ exposures beyond that afforded by the current standards will achieve additional public health benefits.*

- In the first clause, the phrase "no known threshold for harmful $PM_{2.5}$ effects" replaced the earlier phrase "no known safe level of exposure to PM." In the second clause, the phrase "reductions of $PM_{2.5}$ exposures" replaced "reductions to PM," and the phrase "that afforded by" was added to the statement.

***PMRS8**) Although a large fraction of $PM_{2.5}$ is regionally contributed, substantially elevated $PM_{2.5}$ exposures can occur in locations adjacent to local PM sources.*

***PMRS9**) Wildfire PM is a serious contributor to PM health effects; early health studies are of concern; more research on acute and sub-chronic effects is ongoing and urgently needed. Wildfire PM exposure is projected to increase in duration and intensity, due to climate change.*

***PMRS10**) Some species of PM may be more dangerous than others; as yet, no PM species can be exonerated.*

***PMRS11**) Ultrafine particles (UFP), which are present in the air in large numbers, pose a health risk. They generally enter the body through the upper and lower respiratory tract and can translocate to essentially all organs. Compared to fine particles ($PM_{2.5}$), they cause more pulmonary inflammation per unit mass, and are retained longer in the lung.*

- The phrase "upper and lower respiratory tract" replaced "lungs"; the phrase "and can translocate" replaced "but translocate." The phrase "per unit mass" was added.

Particulate Matter Reduction Statements for Revision:

Advisory Council members discussed substantive changes to two Particulate Matter Reduction Statements. Discussion points are summarized beneath the initial version of each substantively revised Particulate Matter Reduction Statement, followed by the revised version.

***Initial PMRS6)** An Air District guideline "target" below the current $PM_{2.5}$ NAAQS may be warranted; if the Air District were to set that target at an annual average of 10 µg/m^3 to as low as 8 µg/m^3, U.S. EPA's $PM_{2.5}$ NAAQS risk assessment provides scientific evidence that annual average targets in that range would save additional lives.*

Discussion: Concern was raised that the phrase "may be warranted" was not strong enough to reflect the weight of the evidence.

***Revised PMRS6)** An Air District guideline "target" below the current $PM_{2.5}$ NAAQS is warranted to protect public health; if the Air District were to set that target at an annual average of 10 µg/m3 to as low as 8 µg/m3, U.S. EPA's $PM_{2.5}$ NAAQS risk assessment provides scientific evidence that annual average targets in that range would save additional lives.*

Initial PMRS7*) Year-to-year variability in meteorological and other weather-related factors cause PM concentrations to vary, even if emissions and other conditions were to remain unchanged.*

Discussion: Confusion was expressed regarding the intent of this statement. Once it became clear that the objective was to ensure the robustness of air quality in the face of changing conditions, the statement was revised to reflect support for strong action.

Revised PMRS7*) Projected increases in wildfire PM exposure, as well as year-to-year variability in PM exposure due to weather-related factors, justifies greater efforts to reduce controllable sources of PM to reduce overall health risk.*

FRAMEWORK DISCUSSION

Advisory Council members agreed on all Framework items, with clarifying revisions to two items as indicated:

F1*) The Air District should move as quickly as possible to take maximal feasible action within its authority.*

F2*) PM reduction strategies should prioritize those measures that are most effective in reducing exposure and improving public health and health equity in the most-impacted areas.*

F3*) The most effective exposure reduction measures may differ across communities, due to varying source mix and size, ambient PM concentration levels, physical circumstances (e.g., meteorology, terrain), and other relevant factors.*

F4*) The Air District should focus PM reduction in areas with elevated exposures, health vulnerability, and those areas with increased impacts and sensitive populations (e.g., U.S. EPA identifies children, non-white, low socioeconomic status, elderly).*

- The phrase “elevated exposures” replaced “increased exposures.”

F5*) PM reduction strategies should consider regional (Bay Area-wide), local (community-level), and localized hot-spot (block-level) sources.*

F6*) PM reduction strategies should consider emission reduction measures for both primary PM and secondary PM formed in the air (e.g., emissions of precursor ROG, NOx, NH_3, and SO_2).*

***F7**) PM reduction strategies will need to address multiple source categories with a wide range of emission reduction measures; there are no single, universal solutions.*

- The text that follows after "multiple source categories" is a new addition.

RECOMMENDED ACTIONS DISCUSSION

Reorganization and Prioritization:

Following the item-by-item discussion described below, Advisory Council members determined that the Recommended Actions should be reorganized into topical groups derived from key concepts expressed in the Particulate Matter Reduction Statements and Framework. Several topical headings were proposed including establishing stricter PM targets, addressing disparate PM exposures and vulnerable communities, addressing wildfire risks and mitigation, and reducing vehicle miles traveled. Advisory Council members agreed that the Recommended Actions should be categorized under such headings, and that any Recommended Actions falling outside of the selected categories might then be considered as lower priorities.

Recommended Actions Approved:

Advisory Council members agreed on the following Recommended Actions. Minor revisions for clarity were made to some items, as indicated:

***RA1**) Establish a $PM_{2.5}$ target consistent with findings based on scientific evidence (i.e., from an annual average of 10 µg/m^3 to as low as 8 µg/m^3.*

- The phrase "based on scientific evidence" was added and "i.e." replaced "e.g."

***RA2**) Continue working to make air quality data for PM and PM precursors more accessible and timely. Partner with effective platforms (e.g., PurpleAir).*

- The phrase "for PM and PM precursors" was added; "platforms" replaced "formats"; "e.g." was added before "PurpleAir."

***RA3)** Make current PM speciation data more available. Advocate for U.S. EPA national monitoring guidance and requirements to increase PM speciation.*

- The word "the" was deleted from where it appeared before "U.S. EPA."

***RA4)** Advocate for increased, broader, national monitoring, exposure, and health impact studies of UFP.*

***RA5**) Advocate for appropriate federal and state agencies to set improved UFP filtration requirements for on-road vehicles.*

***RA7**) Advocate for improved emission estimation and control methods for emerging source categories (e.g., tires and brakes, road dust).*

***RA8**) Develop Air District PM action plans for individual highly impacted communities with appropriate targets.*

***RA9**) Further develop and implement strategies including health protective measures and guidance to protect health during wildfire episodes. Such measures and guidance could include: 1) public education; 2) improved real-time monitoring and forecasting models; 3) more comprehensive research to assess short- and long-term health impacts; 4) assessment of the feasibility of strategies to reduce PM exposure in proposed forest management strategies; 5) establishment of clean air shelters (e.g., in schools, community centers, libraries, senior centers, senior living facilities) with power, HVAC/HEPA filters, personal protective equipment (PPE), etc., especially in disadvantaged communities; 6) mobile clean air shelters; and 7) strategies to provide HEPA filters for in-home high risk individuals.*

***RA10**) Develop, fund, implement, and encourage strategies to reduce vehicle miles traveled (e.g., active transportation, public transit, land use planning, and telework).*

***RA11**) Expand community-level exposure and health impact assessments.*

***RA12**) Evaluate improvements to existing rules limiting visible emissions and trackout of road dust to address communities that are overburdened.*

***RA22**) Assist local programs to control road dust (e.g., analyze road dust emission rates for local streets).*

***RA26**) Seek changes at state level to Air District authority for magnet sources.*

***RA29**) Support CARB efforts to electrify trucks and other vehicles.*

***RA30**) Seek stricter off-road mobile source rules from CARB.*

Recommended Actions for Revision:

Advisory Council members discussed substantive changes to many of the Recommended Actions. Discussion points are summarized beneath the initial version of each substantively revised Recommended Action, followed by the revised version.

Initial RA6) *Strengthen implementation and enforcement of programs and rule intended to reduce exposures to $PM_{2.5}$ (including diesel PM) and seek sufficient resources to do so.*

Discussion:

- Advisory Council members removed qualifying language, striking the word "intended" and replacing "seek sufficient resources" with "ensure necessary resources."

- Specific reference to Rule 11-18 was added.

Revised RA6) *Strengthen implementation and enforcement of programs and rules (including Rule 11-18) to reduce exposures to $PM_{2.5}$ (including diesel PM) and ensure necessary resources to do so.*

Initial RA13*) Modify permitting regulations to address hyper-localized hot-spot health risks.*

Discussion*:* Advisory Council members requested clarification on whether the Recommended Action was intended to address cumulative health risks, expressing support for modifying permitting regulations to take into account pre-existing health risks for communities near the permitting site in determining the potential health impact of permitted sources.

Revised RA13*) Modify permitting regulations to address hyper-localized hot-spot and cumulative PM health risks.*

Initial RA14) *Adopt rules incentivizing/requiring building electrification OR 'Adopt a rule requiring electric appliances rather than gas in new construction.'*

Initial RA15) *Adopt rule to improve the efficiency of water heaters and space heaters and require electrification of new heaters and other appliances.*

Discussion:

- Concern was raised regarding adding stress to the electrical grid, particularly with respect to solar and wind energy production that is lowest in winter when demand is highest due to heating needs. A counterargument was made that while resiliency problems do need to be solved, building stock turns over slowly and requiring all electric in new construction is not anticipated to create an undue burden on energy infrastructure.

- Advisory Council members sought clarification on the scope of the Air District's authority with respect to regulating appliances and systems within homes and other buildings. Air District staff clarified that while the Air District does not regulate indoor air

quality or appliance/system efficiency, it does have the authority to regulate systems that discharge emissions (through exhaust points) into ambient air.

- Air District staff pointed out that the cost of retrofitting all existing buildings in the Bay Area to switch from gas to electric heating would be in the billions and possibly tens of billions of dollars (and therefore orders of magnitude beyond the incentivizing capacity of the Air District).

- Examples of existing and emerging electrification incentive and information programs were shared, including those offered through the Air District as well as state and federal agencies and energy providers.

Revised RA14) *Adopt a rule requiring, and create a program incentivizing, all electric utilities in new construction. Continue to look for opportunities that could include training, incentives, and programs to move our existing built environment to all electric.*

Revised RA15*) Adopt rules to improve the emissions performance of water heaters and space heaters and require electrification of new heaters and other appliances.*

Initial RA16) *Expand the existing rule to reduce emissions from commercial cooking equipment such as charbroilers (Rule 6-2).*

Discussion*:* Advisory Council members argued for a broader recommendation that would include wood-fired ovens and not be limited to one specific rule.

Revised RA16*) Expand efforts to reduce emissions from commercial cooking equipment such as charbroilers and wood-fired ovens.*

Initial RA17*) Update permitting regulations for gas stations and dry cleaners (Regulation 2).*

Discussion*:* Advisory Council members questioned the intent and relevance of this recommendation with respect to PM. Air District staff expressed that both types of businesses are already tightly regulated and most dry cleaners have already switched to using non-toxic compounds.

RA17 was deleted.

Initial RA18*) Adopt amendments to Rule 9-1 to limit sulfur dioxide emissions from refineries.*

Discussion*:* The discussion centered on the spatial and temporal scale of sulfate formation and whether sulfur dioxide emissions have passed out of the Bay Area by the time they influence formation of PM. Because effects on Bay Area air quality are not yet clear, the Recommended Action was reframed as a testing recommendation.

Revised RA18*) Evaluate the efficacy of reducing sulfur in refinery fuel gas as a PM reduction strategy.*

Initial RA19*) Adopt a new rule to limit site-wide health risk from PM.*

Discussion*:* After Advisory Council members expressed confusion about this Recommended Action, Air District staff clarified that while there is presently a rule for toxics that limits the overall impact of a facility, there is no such rule governing PM. Such a rule could require an emissions reduction plan if a facility were to exceed a certain threshold of health risk (using quantifying metrics such as cancer cases per million).

Revised RA19*) Adopt a new rule to limit site-wide impacts from PM emissions.*

Initial RA20*) Take into account cumulative impact in permitting.*

Discussion*:*

- Advisory Council members questioned whether this topic was already covered (see RA13).

- Air District staff clarified the Recommended Action's intent to protect overburdened communities by incorporating considerations of existing hyper-localized PM concentration levels as well as other health vulnerabilities in the community into permitting decisions.

Revised RA20*) Develop strategies to consider cumulative community PM impacts in permitting processes.*

Initial RA21*) Close loopholes that allow piecemealing of larger projects into small components.*

Discussion*:* Discussion centered on whether such loopholes exist in current regulation and whether the "cumulative impacts" guidance captured in RA20 already addressed the issue of total impacts in a specific area, and whether this Recommended Action had a specific function with respect to PM emissions. Air District staff indicated there is legislation to prevent piecemealing as a strategy of regulatory avoidance.

RA21 was deleted*.*

RA23*) Seek federal funding for electrification infrastructure.*

Discussion*:* A suggestion was made to emphasize the need to support electrification in disadvantaged communities.

Revised RA23*) Seek federal funding for electrification infrastructure, especially for disadvantaged communities.*

Initial RA24*) Work to leverage Senate Bill 1 funding to replace switcher engines in East Bay to reduce other off-road sources.*

Discussion*:* Air District staff clarified that railroads are regulated by the federal government, which has not appeared to be receptive to the Air District's advocacy efforts in this regard.

RA24 was deleted*.*

Initial RA25*) Seek additional funding to improve transit, bicycles, and pedestrian facilities, and to reduce VMT to reduce road dust, brake & tire wear, and vehicle exhaust.*

Discussion*:* Advisory Council members emphasized the need to center the Recommended Action on reducing vehicle miles traveled (VMT), clarify the types of initiatives suggested (including specifying public transit), and tie the Recommended Action explicitly to PM reductions.

Revised RA25*) Seek additional funding to reduce vehicle miles traveled (VMT) (e.g., improved public transit, bicycle and pedestrian infrastructure, facilities, and programs) in order to reduce PM from road dust, brake & tire wear, and vehicle exhaust.*

Initial RA27*) Authorize the Air District to regulate fine PM as a toxic air contaminant.*

Discussion*:* Air District staff clarified that:

- the California Air Resources Board (CARB) and Office of Environmental Health Hazard Assessment (OEHHA) are the agencies responsible for designating toxic air contaminants,
- the goal of seeking designation of $PM_{2.5}$ as a toxic air contaminant is to allow the Air District greater regulatory latitude, and
- the Air District is already seeking this designation.

Revised RA27*) Continue efforts to designate fine PM as a toxic air contaminant.*

Initial RA28*) Seek authority for the Air District to establish air quality standards for PM.*

Discussion*:* In light of the results of the 2020 Presidential election, Advisory Council members revised this Recommended Action to reflect their anticipation of greater interest in improving air quality standards at the federal level.

Revised RA28*) Advocate for U.S. EPA to establish more stringent air quality standards for PM.*

Initial RA31*) Seek authorization from CARB for stronger at-berth regulations to control emissions from ships that dock at ports and refineries.*

Discussion*:* Air District staff expressed that regulations already require ships to plug in to electricity at port (to curb diesel PM and NOx emissions), and related standards are stringent.

RA31 was deleted*.*

Initial RA32*) PM action plans should include all available technically feasible methods of reducing PM emissions and exposures for stationary, area, mobile, and indirect sources of PM.*

Discussion*:* Advisory Council members acknowledged that not "all" technically feasible methods should be included, but rather the best available methods that are also feasible in terms of cost.

Revised RA32*) PM action plans should include best available methods that are technically and economically feasible for reducing PM emissions and exposures for stationary, area, mobile, and indirect sources of PM.*

Initial RA33*) Legislative approaches to secure additional authority to regulate PM emissions should be considered, e.g. indirect source rule (ISR) or indoor air quality.*

Discussion*:* With input from Air District staff, Advisory Council members determined that the intent of this Recommended Action was already captured elsewhere.

RA33 was deleted.

Initial RA34*) OEHHA and ARB should be petitioned to identify PM as a toxic air contaminant in light of the available health data.*

Discussion*:* Advisory Council members determined that the intent of this Recommended Action was already captured in RA27.

RA34 was deleted.

Initial RA35) *A comprehensive study of indoor air quality should be conducted to better understand the pathways of PM exposure and how people can reduce that exposure through changes in habits.*

Discussion*:* Air District staff provided examples of other agencies that would be better positioned to conduct such a study and suggested that the Air District could have a role in communicating the resulting information.

RA35 was deleted.

Initial RA36*) PM action plans should include non-traditional partners and approaches such as county health officials, health care providers, and methods of improving indoor air quality. (This could provide added protection during episodic events such as wildfires and facility incidents.)*

Discussion*:* Air District staff clarified that the Air District is already taking the approach described in the Recommended Action.

RA36 was deleted.

INPUT FROM PUBLIC COMMENT

Jed Holtzman of 350 Bay Area, who was given additional time by the Advisory Council to complete his comments, made the following arguments for changes to the Recommended Actions:

- RA1 — Especially in light of wildfire PM, [the Advisory Council] need[s] to aim low. Set the target at 8 µg/m^3 for annual average $PM_{2.5}$ concentration levels.
- RA28 — This authority is needed. Restore the initial version of the Recommended Action calling for the Air District to obtain authority to set air quality standards.
- RA27 — Strike this Recommended Action; the toxics approach is not sought by the affected community and is viewed as "incredibly problematic."
- RA14 — Strengthen the mandate to achieve all-electric in homes in order to combat dire indoor air quality problems.
- RA19 — Do not use the 10-year risk reduction process; it is too slow.
- RA21 — Restore this Recommended Action to prevent the piecemealing of larger projects into smaller components as a loophole to avoid regulation. Cumulative impact is a different concept addressing exposures over time from multiple permitted sources.
- RA15 — Emissions performance is irrelevant if electrification is achieved. A Recommended Action is needed address residential wood smoke.
- RA16 — Strengthen this Recommended Action; call for "maximum feasible action" in the form of robust rules, not just "expand efforts."
- RA18 — Broaden to cover refinery PM in general.

- Overall: "Robustness in recommendations needs to match robustness in the findings."

Charles Davidson, a Hercules resident, also argued for the need to prevent piecemealing of larger projects, pointing to issues that occur when multiple agencies (such as the Air District and county land use authorities) are approving different aspects of one project. He also discussed issues with "industrial, chronic exposures" to indoor air pollution and urged Advisory Council members to remain cognizant of related health impacts in considering standards.

NEXT STEPS

The task of organizing the Recommended Actions into topical categories was assigned to a subcommittee comprising Advisory Council Chair Stan Hayes, Advisory Council member Jane Long, and Advisory Council member Michael Kleinman, who agreed to produce a draft within the week.

The Advisory Council determined that an additional meeting was needed in order to complete deliberations and prepare to submit the final report to the Air District Board of Directors. As the Advisory Council's meeting with the Board of Directors is scheduled for December 16, the additional meeting will need to occur before that date. Air District staff planned to poll Advisory Council members on their availability.

PUBLIC COMMENT SUBMITTED VIA LETTER TO THE ADVISORY COUNCIL

Monday, November 9, 2020

Dear Chair Sinks, Chair Hayes, and Councilmembers,

With so much subject matter to discuss in your meetings, there's no time for pleasantries in three minutes (or six) of public comment, but thank you for your time and thought in service of working through these issues of behalf of the Air District and the health of Bay Area residents. As the primary community stakeholder at the agency, whose staff and members have attended an unfathomable number of Air District policy meetings for the last seven years, and which takes the Air District's success very seriously, we greatly appreciate your serious attention to these serious issues.

Below are some of the comments I made in your November 9 meeting, submitted at your request. I hope they are of help as you work to complete your deliberations.

1. The Council has importantly said in **F1** that, where the Air District has authority, it needs to move quickly to take maximum feasible action. This is the critical kernel coming out of the Council's findings, and this urgency could usefully be carried over to the Recommended Actions section. Advocating for other entities to take an action or seeking funding to pass through, while important secondary parts of the agency's toolkit, do not approach the Air District's core responsibility to meet its public health mission and its core authority under state law to achieve it.

   Demonstrably, the Air District does not have as much trouble with these "soft power" sorts of activities as it does meeting its core regulatory responsibility with respect to stationary and area sources. The dynamic of agency staff actively arguing in your meetings against many of the components and legal frameworks that would make up "maximum feasible action" is a difficult and unfortunately familiar one, but it's important to base recommendations on what is required, not what existing staff feels like doing. It is also important to remember that the policy-making authority of the Air District falls to its elected Board of Directors and not its staff.

2. Especially in light of the huge wildfire PM load we can expect, we need to aim low when setting our targeted concentration from controllable pollution. An 8 mcg/m3 annual average limit + ~4 mcg/m3 annual average contribution from wildfire smoke would still equal 12 mcg/m3, the federal standard that is so injurious to health that it spurred the EPA ISA process and the foundational discussions of this Advisory Council process. So for the purposes of **RA1** and its own associated PMRS, we would suggest leaving the 10 mcg/m3 limit out and focusing on setting the target "as low as 8 mcg/m3 annual average."

3. The recommendation in **RA28** that the District seek authority from the state to set its own tighter air quality standards is critically important, notwithstanding staff's attempts to steer the Council away from it. Setting an air quality standard requires (1) actually making a plan to meet it, (2) taking "all feasible actions" to meet the standard, and (3) reporting in detail about why you didn't meet it and what exactly you are going to do to meet it. It is precisely this robust planning, robust implementation, and robust accountability that the agency's counsel described in your meeting as "additional regulatory overhead" when he said having the authority "doesn't really add much except additional regulatory overhead."

   As far as robust planning, we heard for the first time at your meeting that staff does not intend to develop a comprehensive PM reduction plan—news to the community members who have driven this

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PM process at the District beginning in late 2018. As far as robust implementation, we also saw staff at the meeting advise weakening or striking many of the most actionable recommendations that were originally included under Rules, Permitting, and Authority. And as far as robust accountability, there is certainly no mechanism to assess compliance, engage in adaptive management, and ensure public accountability—nor will there be with a loosey-goosey "target" that the Air District will unofficially set.

Setting a PM standard, being in non-attainment of that standard, and being forced to take "all feasible measures" to address the problem is what is required to shake the agency out of its torpor. Our proposals on PM regulation and discussions with supportive board members beginning two years ago led to this Council proceeding, and even after constant engagement over that time, staff is still attempting to minimize the amount of additional work they will need to do. A little tough love and effective public oversight are overdue.

4. Relatedly, the approach in **RA27** of regulating PM like a toxic air contaminant will be useful for getting at local sources that a regional standard would not address, but will *not* be sufficient on its own to meet a meaningful emissions reduction goal. Our invited presentation to the Council at your May 2020 meeting laid out in detail the agency's stunning and singular failure to implement its hallmark rule purporting to use health risk as a legal framework and forcing mechanism (Rule 11-18). When staff says they want to regulate PM like a toxic , they are saying they intend to use this approach for all regulatory emissions reductions. This would be demonstrably disastrous. Among other glaring flaws, no reductions in deadly pollution—responsible for 2,000 to 3,000 early deaths per year in the region—would begin for several years. How the agency can legally achieve needed PM reductions has been a huge and central focus of staff's communication with the public over this two-year discussion, but this subject was glaringly absent in your meeting today. We need a regional *and* a local approach, as your findings indicate. Effectuating this requires not only regulating PM further like a toxic but also further as a criteria pollutant, which the standard-setting authority discussed in the last point would allow.

5. The Air District is already discussing mechanisms to get rid of natural gas in new construction with 350 Bay Area, Building Decarbonization Coalition, Rocky Mountain Institute, and others. We encourage you to re-strengthen **RA14** and recommend that the District use all its authority to push building decarbonization based on air quality impacts. Staff indicated today that a subset of appliances fall under their existing outdoor air quality authority, however the Board of Directors has received a presentation indicating more NOx is generated indoor from natural gas appliances than is generated from all power plants in the state, with definite impacts to health, and additional standard-setting authority would fill in the gaps here that were causing staff to tiptoe today around pushing an zero-emissions building environment.

6. **RA15** on energy efficiency seemed unnecessary if RA14 is implemented appropriately. Improvements to fossil fuel infrastructure at this late date should primarily employ replacement with feasible zero-emission alternatives. Expanding the discussion in RA14 from new construction to include renovations, replacements, changeouts, etc., will effectively take care of iterative efficiency improvements, reduce GHGs and morbidity, and help reduce over time the looming stock of building retrofits that will need to be done.

7. Woodsmoke has been dropped from this discussion at some point; we're not sure when. But including further controls on wood-burning is still warranted, especially given that we're breathing woodsmoke for weeks to months each year at this point. Please re-include policy recommendations to reduce woodsmoke and any other significant sources of PM in the region.

8. **RA16** is an example of one fairly nondescript rule among *many* that will be required to reduce emissions instead of simply talking about it. It is uncontroversial that this rule needs to be expanded, but as with many, the language was weakened incommensurate with the urgency called for in your

findings and in F1. We need so many rules, robustly implemented and robustly enforced, to meet this challenge—and your recommendations shouldn't shrink away from this inconvenient truth.

9. **RA18** could usefully be broadened to include rules on all significant sources of refinery PM. The communities bordering these facilities are the definition of environmental justice communities, whose long-disproportionate impacts to health and life must be addressed. Even now, heated discussions are underway at the agency about amendments to Rule 6-5 on refinery fluid catalytic cracking units, the largest single source of PM at the facilities. Sulfur is just one element, no pun intended.
10. The site-wide health risk approach in **RA19** is essentially a Rule 11-18 for PM. Again, see our May presentation to the Council and Air District staff's own reports to the Board of Directors on this rule for an illustration of its unfortunately fatal flaws. This is a losing approach to addressing this critical and deadly pollution burden, and it's one the community will not support.
11. In regards to **RA20** and **RA21**, cumulative impact and piecemealing are definitely two separate issues of permitting. Cumulative impact refers to the impacts to overburdened communities over time. Currently, an air permit is approved if it meets its own internal conditions, regardless of whether that new emissions source is the first significant source on the block or the hundredth. Addressing cumulative impact in permitting in RA20, which Air District staff says they are pursuing, would take the actual spatial and temporal emissions environment into account for the benefit of giving overburdened and disproportionately impacted communities an overdue break.

    Piecemealing, on the other hand—which Air District staff has no intention of addressing for fear of upsetting the fossil fuel industry and other deep-pocketed parties—refers to separating a large project into smaller pieces to avoid regulation of various kinds, including Air District permit rules and emissions regulations. People live and die based on whether Air District legal staff classifies a refinery proposal as two or more "minor modifications" instead of one "major modification," to use just one example.

Thank you again for the extra speaking time at your meeting and for the consideration of these comments as your pursue and complete your deliberations. The Advisory Council proceedings on PM that are winding to an end here are well ahead of the discourse at the state level, to say nothing of the federal, and relying on those levels of government to lead on PM reduction is misplaced. The Air District can and should lead with maximal feasible and innovative action on PM to save lives, address its mission, and do so in a timely manner. Your strong recommendations will be key to the region's success.

Best regards,

Jed Holtzman

Senior Policy Analyst

Particulate Matter:
Spotlight on Health Protection

Appendix C: Symposium Summaries and Presentations

Particulate Matter:
Spotlight on Health Protection

Symposium Summary: Health Effects and Exposures and Risk

October 28, 2019

Bay Area Air Quality Management District

Table of Contents

Executive Summary

On October 28, 2019, the Bay Area Air Quality Management District (Air District) convened a symposium, at the request of its Advisory Council, to obtain input from leading experts on the best available science concerning impacts of particulate matter (PM). The morning panel focused on PM health effects; the afternoon panel focused on PM exposure and risk. After hearing from national and state air quality experts on the panels and from community members during public comment periods, the Advisory Council drafted the following Sense of the Advisory Council statement:

> **The current PM standards are not adequately health protective. Further reductions in particulate matter will realize additional health benefits. We ask the Air District staff to bring forward with urgency options within the legal authority of the Air District that would further limit PM exposure, especially in high-risk communities.**

This consensus was reached upon consideration of information presented by the panelists and public commenters demonstrating: adverse health effects of PM, including mortality, at concentrations below the current standard; disproportionate burden of PM exposure and risk on disadvantaged communities, including those within the Air District; and emerging evidence of the health impact of ultrafine particles (UFP) and wildfires, both of which are understudied.

PM Health Effects

Draft PM ISA. Jason Sacks**,** Project Lead on the Particulate Matter Integrated Science Assessment (PM ISA) and Senior Epidemiologist at the Environmental Protection Agency's (EPA) National Center for Environmental Assessment, reviewed the structure and findings of the Draft PM ISA (https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter). His presentation demonstrated that PM causes more health problems than previously known, at lower concentrations than previously known, and disproportionately affects vulnerable populations. In particular, the Draft PM ISA found new causal or likely-to-be causal associations between nervous system effects and long-term exposure to $PM_{2.5}$ and, independently, to the portion of $PM_{2.5}$ considered to be ultrafine particles (UFP), and between cancer and long-term exposure to $PM_{2.5}$. Children and non-white populations are at increased risk of adverse health effects of PM, and there is no evidence of a concentration threshold below which effects are not observed.

Mechanisms of PM impact. Advisory Council Vice Chair Michael Kleinman, Professor of Environmental Toxicology at UC Irvine and Co-Director of the Air Pollution Health Effects Laboratory, focused on the formation, composition, and mechanistic health effects of PM and new insights from his research concerning the toxicity of PM. He discussed how the connection between PM and health effects can be traced mechanistically, with oxidative stress from biological reactions to PM leading to inflammation, cell death, and cardiovascular events. He

also discussed how the toxicity of PM may be attributable to its coating rather than its core, although metals in the core can also produce health effects.

PM burdens and wildfire impacts. Dr. John Balmes, Professor of Medicine at UC San Francisco, Professor of Environmental Health Sciences at UC Berkeley, and Director of the Northern California Center for Occupational and Environmental Health, covered numerous topics associated with particulate matter including sources, effects, challenges with UFP, disproportionate burdens of exposure, and wildfire impacts. His presentation demonstrated that PM exposure leads to a wide range of health problems and disproportionately affects low-income communities and people of color, who suffer cumulative impacts from multiple exposures and disadvantages. In California, exposure to wildfire smoke is associated with increases in health care utilization for both respiratory and cardiovascular problems.

Independent PM Review Panel. Christopher Frey, Chair of the Independent Particulate Matter Review Panel and Glenn E. Futrell Distinguished Professor of Environmental Engineering at North Carolina State University, explained how recent changes to the review process for the federal National Ambient Air Quality Standards (NAAQS) led to the formation of the Independent Particulate Matter Review Panel. He summarized the conclusions of that panel:

- The scientific evidence for $PM_{2.5}$ health effects is robust.
- The current $PM_{2.5}$ standards are not adequately protective of public health.
- The annual standard should be lowered to 10 micrograms per cubic meter ($\mu g/m^3$) to 8 $\mu g/m^3$ (versus the current 12 $\mu g/m^3$ standard).
- The 24-hour standard should be lowered to 30 $\mu g/m^3$ to 25 $\mu g/m^3$ (versus current 35 $\mu g/m^3$ standard).
- These changes would save thousands of lives.
- The PM_{10} standard should be adjusted downward consistent with these changes.
- There appears to be no threshold; lower levels would produce still greater benefits.
- For African Americans, the relative risk of health impacts from PM is three times higher than for the U.S. as a whole.

<u>PM Exposures and Risks</u>

OEHHA research. Lauren Zeise, Director of the California Office of Environmental Health Hazard Assessment (OEHHA) and Leading Developer of CalEnviroScreen, described some of OEHHA's current research efforts to understand the relationships between specific PM sources and community health outcomes. After explaining that there is great variability in the relationship between PM concentration and health risk, she discussed how OEHHA is conducting biomonitoring studies to track whether biomarkers indicate reductions in risk following reduced air pollution concentrations. These data, along with indoor air samples, questionnaires, activity diaries, and information from GPS trackers, will be combined with source pollution mapping data to determine how exposures are occurring. Dr. Zeise also demonstrated that wildfires are causing PM standards to be exceeded for both 24-hour and annual averages. OEHHA is presently investigating relationships between the 2017 Northern California Wildfires and

numerous health outcomes in the area including respiratory, cardiovascular, and neurological problems.

Silver buckshot, not silver bullet. Julian Marshall, Kiely Endowed Professor of Civil & Environmental Engineering and Adjunct Professor of Global Health at the University of Washington, described an approach to reducing health risks from PM involving combined analysis of sources of emissions, concentrations at geographical locations, levels of exposure to different sources of emissions, and racial and income disparities affecting environmental justice. Because PM comes from many sources, he concluded that reducing PM exposure requires many strategies, describing this approach as "silver buckshot, not a silver bullet." With respect to health risks from PM, he demonstrated that income matters, and race matters, but race matters more than income. To get the most "bang for the buck" on health impacts, he argued that interventions should focus on areas where high impact from PM meets high inequity in terms of environmental justice.

Draft PM Policy Assessment. Scott Jenkins, Project Lead on the EPA's review of National Ambient Air Quality Standards for PM and Senior Environmental Health Scientist in EPA's Office of Air Quality Planning and Standards, presented an overview of the approach and conclusions of the EPA's Draft PM Policy Assessment completed in response to the Draft PM ISA. The PM Policy Assessment featured a risk assessment indicating that thousands of lives per year in the U.S. could be saved if annual average $PM_{2.5}$ concentrations are reduced. The assessment included an argument for revising the annual $PM_{2.5}$ standard downward based on the science, as well as a discussion of how retaining the current standard could be justified by placing very little weight on the epidemiological evidence and risk assessment and greater weight on the uncertainties and limitations of the data.

West Oakland Community Action Plan. Phil Martien, Director of Assessment, Inventory, & Modeling for the Air District, described the analysis conducted for the recently completed West Oakland Community Action Plan, the first in a series of community emissions reduction programs that the Air District is developing in response to California's Assembly Bill 617 legislation (AB 617). Per the community's requests, the study took a hyperlocal approach, modeling block-by-block exposures. Disparate exposure levels were seen within West Oakland: the cleanest blocks are experiencing on average 3 $\mu g/m^3$ lower PM concentrations than the most polluted blocks. Sources of PM also differed, with some areas experiencing $PM_{2.5}$ emissions primarily from street traffic and others experiencing the greatest proportion of $PM_{2.5}$ emissions from highways or permitted sources. The West Oakland Community Action Plan demonstrates how hyperlocal modeling can be accomplished, but also highlights the need for other agencies to act, such as California Air Resources Board (CARB), the City of Oakland, and the Port of Oakland, in order to reach community emissions reduction targets.

<u>Public comment</u>

Public comment was taken during two designated periods during the event. The general sentiment expressed by many commenters was, "We need action, not more discussion."

Several people spoke about their personal experiences with toxic emissions in their neighborhoods. The disproportionate impact of air pollution on disadvantaged communities was a central point of focus.

Discussion and Deliberation

The discussion between the Advisory Council and the morning panel focused on cost considerations and the appropriateness of a "no safe level" stance, and broached the topic of recommending Air District priorities, which led to further discussion regarding the monitoring of ultrafine particles. The discussion between the Advisory Council and the afternoon panel was brief and comprised of one question concerning margin of safety considerations in the Draft Policy Assessment (which Dr. Jenkins clarified was the exclusive domain of the EPA Administrator).

The Advisory Council's deliberation followed, resulting in the Sense of the Advisory Council statement presented above. Advisory Council members also expressed interest in further exploring the potential for:

- Treating PM as a toxic;
- Monitoring ultrafine particles;
- Encouraging the State of California to adopt stricter PM standards;
- Ensuring local permits are consistent with the PM standard supported by the science;
- Disaggregating solutions with climate co-benefits, solutions unrelated to climate strategies, and emergencies;
- Identifying strategies to maximize impact or "bang for the buck"; and
- Creating an Air District Implementation Plan.

Next Steps

The Advisory Council will reconvene on December 9, 2019. During that meeting, in response to the Advisory Council's requests, the Air District will present on its current activities to reduce PM exposures, including monitoring of ultrafine particles. It will also discuss additional "options within the legal authority of the Air District that would limit PM exposure, especially in high-risk communities," in accordance with the Sense of the Advisory Council, in order to inform the Advisory Council's advice to the Air District's Board of Directors. The Advisory Council is expected to receive and comment on this symposium summary document during the December 9 meeting.

Planning continues for a second PM symposium focused on community and other stakeholder input and engagement; the event will take place in Spring 2020.

Background

On October 28, 2019, the Bay Area Air Quality Management District (Air District) convened a symposium, at the request of its Advisory Council (Council), in order to obtain input from leading experts on the best available science concerning health effects of particulate matter (PM). Serving as an official meeting of the Advisory Council, which advises and consults with the Air District's Board of Directors and Executive Officer on technical and policy matters, the symposium sought to discuss:

PM Health Effects

- what health effects are observed from PM exposure, including exceptionally high acute PM exposures (e.g., wildfire smoke);
- what biological systems are affected and by what mechanisms;
- what population groups are most at risk; and
- what uncertainties are most relevant.

PM Exposure and Risk

- what the emission sources are that contribute to PM;
- what exposures to airborne PM occur and to whom;
- what health risks are posed by those PM exposures; and
- what subset of sources contribute most to PM risk, particularly in the most highly impacted communities.

The symposium followed several relevant policy developments at the state and federal levels. In California, Assembly Bill 617 passed in 2017 directing the California Air Resources Board and all local air districts to protect communities disproportionally impacted by air pollution. Implementation in the Bay Area Air Quality Management District to date includes the development of a community-led plan for air quality improvement in West Oakland (adopted by the Air District's Board of Directors in October 2019) and an air quality monitoring program for the Richmond area (underway).

At the federal level, staff of the Environmental Protection Agency (EPA) released a Draft Integrated Science Assessment (ISA) for Particulate Matter (PM) in October 2018, followed by a Draft PM Policy Assessment regarding the standard-setting implications of the PM ISA in September 2019. These drafts were submitted for review to the Clean Air Scientific Advisory Committee (CASAC), which provides advice to the EPA Administrator on the setting of national ambient air quality standards. Additionally, a separate, independent response to both EPA draft documents was released in October 2019 by the Independent Particulate Matter Review Panel, whose members served previously on the CASAC PM Review Panel until their dismissal in October 2018 by EPA Administrator Andrew Wheeler.

The timing of the symposium also coincided with the outbreak of the Kincade Fire in Sonoma County and associated evacuations. Additionally, widespread power outages within the Air

District's jurisdiction were intentionally executed by Pacific Gas & Electric (PG&E) as wildfire prevention measures given the dry conditions and high winds. This crisis formed a backdrop to the proceedings.

Particulate matter experts presenting at the event included the lead authors of the EPA PM ISA (Jason Sacks), the EPA PM Policy Assessment (Dr. Scott Jenkins), the Independent Review Panel document (Professor Christopher Frey), and the West Oakland Community Action Plan (Dr. Phil Martien). They were joined by Independent Particulate Matter Review Panel Members Professor Michael Kleinman and Dr. John Balmes, Director of the California Office of Environment Health Hazard Assessment Dr. Lauren Zeise, and University of Washington Professor Julian Marshall. These speakers were organized into a morning panel focused on PM health effects and an afternoon panel focused on PM exposure and risks.

The event, which was open to the public, included two public comment periods. The midday lunch break featured a keynote address by former EPA Administrator Gina McCarthy, who also answered questions from community attendees.

The morning and afternoon panels were each followed by joint discussions between the Advisory Council members and panelists. The event concluded with a brief Advisory Council deliberation.

The event was shared live via webcast, the video archive of which can be viewed at http://baha.granicus.com/MediaPlayer.php?clip_id=6194.

Morning Panel: PM Health Effects

Current State of Particulate Matter Science: Particulate Matter Integrated Science Assessment (Working Draft Conclusions)

Jason Sacks
Project Lead, Particulate Matter Integrated Science Assessment (PM ISA)
Senior Epidemiologist, National Center for Environmental Assessment, EPA

Main takeaway	**PM causes more health problems than previously known, at lower concentrations than previously known, and disproportionately affects vulnerable populations.**

Presentation Summary

Mr. Sacks reviewed the structure and findings of the initial draft of the EPA's recent Particulate Matter Integrated Science Assessment (PM ISA), which aims to provide an updated review of the science in order to assist federal rulemaking. The Draft PM ISA addresses the question:

> *"Is there an independent effect of PM on health and welfare at relevant ambient concentrations?"*

The PM ISA drafters reviewed the body of new research since 2009 including epidemiological studies, animal toxicological studies, and controlled human exposure studies at PM levels analogous to ambient concentrations in U.S. communities.

The Draft PM ISA can be found at https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter.

Health effects. The Draft PM ISA found new causal or likely-to-be causal associations between:

- Nervous system effects and long-term exposure to $PM_{2.5}$ and, independently, to the portion of $PM_{2.5}$ considered to be ultrafine particles (UFP)
- Cancer and long-term exposure to $PM_{2.5}$

The science also confirmed and strengthened the evidence of previously known causal or likely-to-be-causal associations between respiratory, cardiovascular, and mortality effects of both short- and long-term exposure to $PM_{2.5}$. Additional PM exposure associations with metabolic and reproductive effects suggested causality but did not meet the strict criteria for "causal" or "likely-to-be-causal," often due to a limited quantity of data.

At-risk populations. Children and non-white populations are at increased risk of adverse health effects of PM. Further evidence regarded as "suggestive" points to increased health risk for people with low socioeconomic status, overweight and obese populations, people with pre-existing cardiovascular and respiratory disease, and people with certain genetic variants.

Chemical components of PM. The evidence does not indicate that any one specific chemical component of PM is a disproportionate concern over others.

Advisory Council Q&A with Panelist

No threshold. Council Member Rudolph inquired whether any evidence supported a threshold concentration value below which health effects from $PM_{2.5}$ could not be observed. The panelist responded that there does not appear to be any such threshold.

Changes to health effect determinations. Chair Hayes requested further clarification on the new findings from the ISA since 2009, which are outlined above and in Slide 15 of the presentations.

Relevance of animal studies concerning UFP. Council Member Solomon asked if there was any reason to question whether results seen in animal studies concerning UFP would be consistent with human health effects. The panelist replied that the inconsistency was in the size of the particles considered to be UFP. There has not been a consistent metric or definition for UFP, which has limited the ability to draw conclusions.

Publication bias. Council Member Borenstein inquired whether studies with null results were being published; if not, there may be a concern that the presentation represented only the fraction of research that observed positive associations with health effects. The panelist clarified that this concern drove the decision to focus on multi-city studies in order to ensure that null results would be incorporated.

Wildfires and sub-daily exposures. Given the Kincade Fire that was burning at the time of the event, Chair Hayes inquired about the influence of sub-daily exposures to high levels of PM. The panelist responded that there are some controlled human exposure studies that would be equivalent to a person walking along a busy road, during which some changes in cardiac and lung function have been observed, but sub-daily studies are scarce and he was not aware of research that would be directly relevant to wildfire exposures.

Particulate Matter: A Complex Mixture that Affects Health

Michael Kleinman
Professor of Environmental Toxicology, University of California, Irvine
Co-Director, Air Pollution Health Effects Laboratory

Professor Kleinman is also Vice Chair of the Air District's Advisory Council.

Main takeaways	**PM can be mechanistically and causally linked to cardiovascular health effects. The toxicity of PM may be more attributable to its coating than its core, although metals in the core can also produce health effects.**

Presentation Summary

Professor Kleinman's presentation focused on the formation, composition, and mechanistic health effects of PM and new insights from his research concerning the toxicity of PM.

Basic PM process. A key source of PM is the combustion of fossil fuels. After these fuels break down during combustion, they cool, become radicalized, and agglomerate. Additional chemicals adhere to these particles and can form highly toxic compounds that may include contaminants such as chlorine, bromine, and metals. When these particles are inhaled and enter the respiratory tract, they can react with proteins and fluids in the lungs and release highly reactive free radicals, causing chemical imbalances throughout the body. If these free radicals overwhelm the body's antioxidant self-protection capabilities, the process can result in inflammation, cell death, and organ failure. Because oxidative stress can oxidize lipids in the blood, it can also lead to the development of atherosclerotic plaque and coagulation factors that can contribute to cardiovascular events such as stroke and heart attack.

"The icing, not the cake." Professor Kleinman's laboratory experimented with removing the organic coating from ambient air particles to which animals were exposed to determine whether, in the words of Chair Hayes, the problem was "the icing or the cake." They found that stripping the particles of their organic coating appeared to mitigate their toxicity.

Additional key points:

- Data limitations concerning chemical components. $PM_{2.5}$ total mass is regarded as a more relevant concern than specific components within it, but this may be due to the much smaller database available for chemical components than for $PM_{2.5}$ as a category.
- Measurement challenges. Ultrafine particles are difficult to measure and monitor because they have almost no mass.
- Risks for California. Sunlight, which is plentiful in California, is involved in the formation of pollutants. In addition to PM, health is also affected by air pollutants such as ozone, which is a strong oxidant. The combined effects of PM and ozone, which can be

experienced in the same day, may cause high levels of oxidative stress. Additionally, Professor Kleinman's research indicates that particles formed on warmer days result in worse health effects than those formed on cooler days, which portends additional problems in an era of climate change.

Advisory Council Q&A with Panelist

Incomplete combustion and control technology. Council Member Long inquired whether UFP resulted from incomplete combustion and whether newer technologies were effective in controlling their formation. The panelist responded that to his knowledge all combustion resulted in the formation of ultrafine particles (along with other particles). He noted that although modern diesel engine afterburner controls denuded particles in a manner similar to his animal toxicology experiments, they also produced high amounts of UFP.

Greenhouse gas impacts. Council Member Rudolph asked whether the process of stripping components from PM would change the release of carbon dioxide from combustion, emphasizing that "climate change is the greatest existential threat to human health right now." She questioned whether targeting the toxicity of the results of combustion should be a goal rather than trying to reduce combustion itself in order to reduce greenhouse gas emissions. The panelist shared his view that in the short-term "we can improve public health by mitigating what we're making right now," while in the long-term pursuing strategies to reduce reliance on fossil fuels.

Particulate Matter Health Effects: What Do We Know and What Do We Still Need to Know?

John Balmes, M.D.
Professor of Medicine, UC San Francisco
Professor of Environmental Health Sciences, UC Berkeley
Director, Northern California Center for Occupational and Environmental Health

Main takeaways	**PM exposure leads to a wide range of health problems and disproportionately affects low-income communities and people of color, who suffer cumulative impacts from multiple exposures and disadvantages. In California, exposure to wildfire smoke is associated with increases in health care utilization for both respiratory and cardiovascular problems.**

Presentation Summary

Dr. Balmes covered numerous topics associated with particulate matter (PM) including sources, effects, challenges with UFP, disproportionate burdens of exposure, and wildfire impacts.

Sources of PM. PM derives not only from combustion particles, but also from crustal and biological sources; for example, road dust is a significant source of PM. Dust particles may carry biological components that can cause health effects.

Health effects. In addition to re-emphasizing the health effects covered in Mr. Sacks' and Professor Kleinman's presentations, Dr. Balmes further noted:

- the smaller the particle, the farther it travels into the body, with some PM particles small enough to enter the bloodstream and even cross the blood-brain barrier;
- $PM_{2.5}$ is associated with increased risk of metabolic effects, including diabetes;
- fetal $PM_{2.5}$ exposures can result in low birth weight, pre-term birth, and changes in gene expression; and
- brain inflammation from PM can affect both ends of the life spectrum - neurodevelopment and neurodegeneration.

Challenges with UFP. As mentioned by previous presenters, because UFP is not regulated independently from other $PM_{2.5}$, there is limited monitoring, which presents challenges for epidemiological research, although toxicological studies suggest UFP is a high-risk hazard. Further, innovations designed to reduce climate change impacts, such as gasoline direct injection, can result in higher UFP emissions.

Disproportionate burdens and cumulative impacts. People of color and people with low socioeconomic status are more likely to be exposed to PM, and the risk from these exposures is compounded by the lack of health-promoting resources in these communities such as health

care, fresh produce, and green spaces. Dr. Balmes shared the example of Richmond, CA, which is within the Air District's jurisdiction. People living in the Liberty/Atchison Villages in Richmond are next to the railyard, near the freeway, next to the General Chemical Corporation (which recently had a serious accident), and downwind from the Chevron Refinery. Stating, "This cumulative risk concept is something that we need to be including in our thinking about air quality management," Dr. Balmes also noted that the Air District is a leader in this regard.

Wildfires. While acknowledging that "we need to know more than we currently do," Dr. Balmes asserted that there is a well-known association between wildfires and increased health care utilization for people with respiratory conditions such as asthma and chronic obstructive pulmonary disease. Additionally, a recent California study associates wildfire smoke with cardiovascular events including heart attack, stroke, and heart failure.

Advisory Council Q&A with Panelist

Wildfire contribution to cumulative impact. Council Member Rudolph asked whether wildfires should be understood as an additional layer of cumulative impact. The panelist responded that although he hadn't considered that framing, it was accurate, as people with lower socioeconomic status are those most likely to be without the means to relocate during wildfires. Rural agricultural workers are one example of a community that may be working outdoors despite poor air quality from wildfires. Council Member Rudolph asked whether it was accurate to say, "It's even more important to reduce our baseline exposures because we know these acute exposures are going to be happening more frequently" due to climate change, or if the two issues of baseline and acute exposures should not be viewed as interrelated. The panelist asserted that Council Member Rudolph's statement was accurate.

Bay Area studies? Referring to slide 76, which mapped Los Angeles county data comparing the distribution of non-white people and people living in poverty alongside the distribution of cumulative air quality hazard, Council Member Solomon asked whether the same analysis could be performed for the Bay Area. The panelist replied that although he was not aware of such an analysis having been performed, it should be possible. He indicated that he would speak with an expert he believed to be capable of executing the task.

Recent Developments in the Scientific Review of the National Ambient Air Quality Standards for Particulate Matter

Christopher Frey
Chair, Independent Particulate Matter Review Panel
Glenn E. Futrell Distinguished Professor of Environmental Engineering, North Carolina State University

Main takeaways	**The federal administration truncated the National Ambient Air Quality Standard science review process and purged the Clean Air Scientific Advisory Committee (CASAC) and the supporting CASAC PM Review Panel of critical scientific expertise. The scientists who were dismissed from the CASAC PM Review Panel continued their review work independently and found that the current PM standards are insufficient to protect public health.**

Presentation Summary

Professor Frey explained how recent changes to the review process for the federal National Ambient Air Quality Standards led to the formation of the Independent Particulate Matter Review Panel. He then summarized the conclusions of that panel, which he leads.

Federal PM Review

Process: The scientific review process that for four decades involved an iterative sequence of assessments flowing from science to policy has been severely abridged. Notably, the EPA's PM Policy Assessment (PA) must now be finalized without reviewing the EPA's final PM Integrated Science Assessment (ISA). Additionally, members of the Clean Air Scientific Advisory Committee (CASAC) PM Review Panel were dismissed, leaving the current CASAC without, by its own admission, the necessary expertise to respond to the documents. Acknowledging the good work accomplished by EPA staff in completing the Draft PM ISA and Draft PM PA in difficult circumstances, Professor Frey emphasized the need for the Air District "to look elsewhere than the EPA's Chartered Clean Air Scientific Advisory Committee" for guidance on PM science review.

Findings: As of October 25, 2019, the remaining six CASAC members were split 4-2 on their national ambient air quality standards (NAAQS) recommendations, with the majority supporting retaining all current standards.

Independent Particulate Matter (PM) Review Panel

Process: Led by Professor Frey, the scientists that were dismissed from the CASAC PM Review Panel continued to meet, without compensation, to complete the public service to which they had committed as CASAC PM Review Panel members. With logistical support from the Union of

Concerned Scientists, the Independent PM Review Panel met for two days in October 2019 and developed a consensus report that was sent to the EPA Administrator. The report and the video-recorded proceedings can be accessed at https://ucsusa.org/meeting-independent-particulate-matter-review-panel.

Findings: The scientific evidence for $PM_{2.5}$ health effects is robust. The current $PM_{2.5}$ standards "are not protective of public health, not even close."

- The annual standard should be lowered to 10 µg/m^3 to 8 µg/m^3 (versus the current 12 µg/m^3 standard)
- The 24-hour standard should be lowered to 30 µg/m^3 to 25 µg/m^3 (versus the current 35 µg/m^3 standard)
- These changes would save thousands of lives
- The PM_{10} standard should be adjusted downward consistent with these changes
- There appears to be no threshold; lower levels would produce still greater benefits
- For African Americans, the relative risk of health impacts from PM is three times higher than for the U.S. population as a whole

See Slides 102 and 103 for Professor Frey's rapid-fire answers to questions posed by the Air District.

Advisory Council Q&A with Panelist

Response to Independent PM Review Panel. Council Member Long asked whether the Independent PM Review Panel received a response from the EPA Administrator or had been mentioned in the press. The panelist replied that the Administrator had not responded, but may not yet have received the report. However, the Independent PM Review Panel also submitted their report as public comment to CASAC, and several CASAC members referred to the report during their deliberations on October 25, 2019. There has been some press coverage of the Independent PM Review Panel, for example in the *Guardian* and *Rolling Stone*.

Safety at 8 µg. Council Member Solomon expressed the concern that, if there is no threshold below which health effects cannot be observed, 8 µg/m^3 cannot be regarded as safe, particularly for vulnerable individuals. The panelist replied that the recommendation is given within the policy context of national ambient air quality standards (NAAQS) and is intended to support a standard that could withstand judicial review. The number is based on the available science, which focuses on ambient air pollution levels observed in epidemiological studies. The Clean Air Act requires that the standards protect public health "allowing an adequate margin of safety," which should protect the general population and at-risk groups, but will not necessarily protect every individual.

The post-presentation Q&A segued into the general discussion between the Advisory Council and the PM Health Effects panel. This discussion is described in the following section.

PM Health Effects: Discussion Summary

The discussion between the Advisory Council and the morning panel focused on cost considerations and the appropriateness of a "no safe level" stance and broached the topic of recommending Air District priorities, which led to further discussion regarding UFP.

Cost considerations and appropriateness of "no safe level" language. Council Member Borenstein expressed discomfort with the language of "no safe level" of PM, emphasizing the need to assess the costs, including health costs, of implementing more stringent standards and using the analogy of motor vehicles to demonstrate that all areas of safety concern must accept some risks. Professor Frey responded that the U.S. Supreme Court's interpretation of the Clean Air Act expressly forbids cost considerations in setting National Ambient Air Quality Standards and stated that voluntary activities such as driving should not be equated to the involuntary act of breathing. He also clarified that the conclusion "there is no evidence of a threshold" is not in itself an argument for banning all particulate emissions. Dr. Balmes addressed the topic from his perspective as a physician member of the California Air Resources Board (CARB). He clarified that whereas CARB does consider economic impacts, the Independent PM Review Panel, following the procedures that had until recently governed CASAC, was restricted from mingling health and economic concerns. He also emphasized that while the most precautionary stance would consider levels below 8 $\mu g/m^3$, the lack of data on lower levels of exposure makes it appropriate to recommend 8 $\mu g/m^3$ for a present limit. In response to a question from Council Member Solomon, Professor Frey clarified that this 8 $\mu g/m^3$ recommendation did take into consideration the increased sensitivity to pollution impacts of African American populations.

Recommending Air District priorities. Chair Hayes asked for guidance in identifying the most important areas of focus for the Air District, given the science and the particular challenges for the area, including wildfires. Dr. Balmes emphasized the need for community-level monitoring in accordance with AB 617 to identify air pollution "hot spots" and hypothesized that black carbon, a form of PM, may be a vital concern for these communities. He also expressed support for monitoring ultrafine particles (UFP) and collecting epidemiological data concerning wildfires. Council Member Long emphasized the need for a strategic plan.

Ultrafine particles. The discussion of UFP continued with Mr. Sacks underscoring that while animal toxicological studies show effects of UFP, little is known about UFP's effects on the human population. One challenge for such research is that particles emitted as UFP may not stay in that size range. He further noted that UFP are contained within $PM_{2.5}$ and efforts to control $PM_{2.5}$ therefore may also bring down UFP concentrations. In response to Chair Hayes' requests for guidance regarding UFP, Professor Frey suggested establishing monitoring stations in carefully selected locations as a long-term strategy and public education/consumer ratings regarding automobile ventilation and filtration systems as more immediate tactics. Professor Kleinman noted that there may be an opportunity for regulation to stimulate innovation with respect to decreasing UFP emissions and that the European Union already requires vehicles to share "particle numbers" regarding in-cabin air quality.

Afternoon Panel: PM Exposure and Risk

Exposure and Risk Panel
Particulate Matter: Spotlight on Health

Lauren Zeise
Director, California Office of Environmental Health Hazard Assessment
Leading Developer, CalEnviroScreen

Main takeaways	**There is a high degree of variability among individuals in the relationship between PM exposure concentration and health risk. OEHHA is pursuing research to determine the most important sources of air pollution with respect to health effects. Wildfires are causing PM standards to be exceeded for both 24-hour and annual averages.**

Presentation Summary

After explaining how health risks from PM can vary, OEHHA Director Zeise described some of OEHHA's current research to understand the relationships between specific PM sources and community health outcomes. She also shared some initial data on PM levels from wildfire.

Variability. There is a high degree of variability in concentration-response relationships relating PM exposure concentration to resulting health risks, due to multiple factors including:

- variable individual vulnerability (e.g., health status, genetic factors, demographic factors)
- variable doses at a given concentration (e.g., breathing rates, other physiological factors)
- variable concentrations within a location (e.g., in West Oakland, can be five times higher)

Given this variability, one way to get the most "bang for the buck" is to focus on improving air quality in communities with the highest exposures and highest vulnerabilities.

Current research at OEHHA. Several relevant studies are underway in alignment with AB 617 that will provide valuable input to PM risk management efforts. A key feature of these studies is biomonitoring to determine whether biomarkers indicate reductions in health risk following reduced air pollution concentrations. For example, the East Bay Diesel Exposure Project is a pilot study measuring exposure to diesel exhaust among community residents. This project collects urine samples in addition to indoor air samples, questionnaires, activity diaries, and information from GPS trackers. These data collected from residents will be combined with source pollution mapping data to determine how exposures are occurring.

Wildfires. PM concentrations during the 2017 Napa Wildfire reached 24-hour averages close to 200 $\mu g/m^3$ and one-hour averages above 300 $\mu g/m^3$ in some areas. In West Oakland, wildfire

impacts on PM have driven annual averages above the national standard, to 12.9 µg/m^3 in 2017 and 14.4 µg/m^3 in 2018. OEHHA is presently investigating relationships between the Napa Wildfire and numerous health outcomes in the area including respiratory, cardiovascular, and neurological problems.

Advisory Council Q&A with Panelist

Wildfire research outcomes. Chair Hayes asked if any preliminary health outcome results could be shared from the Napa Fire study, to which the panelist replied that she could not yet share results but expected to do so in the near future. Chair Hayes also asked if OEHHA would be including other years in the study. The panelist replied that while the Napa Fire study is a stand-alone project, the OEHHA epidemiology team has also been involved in a study of primates (macaques) in captivity that tracks outcomes to exposure to wildfires that occurred in 2008. This natural experiment of mother-infant pairs indicates that the exposure resulted in impacts on lung function and immunological markers. Chair Hayes remarked that such findings were consistent with studies in Southern California indicating issues with lung function in children.

Communicating importance of sub-daily exposures. Council Member Borenstein introduced the topic of communicating with the public about risks and precautions, citing the example of a group of teenage girls, presumably a high school track team, who were running, outdoors, while a nearby wildfire caused the air quality index (AQI) to be over 150. The panelist agreed that there is a need for more effective communication strategies and highlighted the misconception that filtration masks allow the wearers to safely exercise outdoors. She referenced a forthcoming meeting in Sacramento in April that will bring together representatives from OEHHA, EPA, Center for Disease Control (CDC), National Institute of Health (NIH), and other agencies to specifically discuss how to advise the public with respect to filtration.

Approaching PM as a non-threshold contaminant. Council Member Solomon inquired about the process for quantifying risk if PM is approached as a non-threshold contaminant. The panelist replied that while it was a difficult task that would involve creating estimates of risk that would differ across communities, it can be done and she anticipates that “working together we can come up with approaches to implement pretty soon.”

Location- and source-specific strategies: Consider impact, marginal impact, and environmental justice

Julian Marshall
Kiely Endowed Professor, Civil & Environmental Engineering, University of Washington
Adjunct Professor, Global Health, University of Washington

Main takeaways	**Reducing PM requires many strategies: "silver buckshot, not a silver bullet." With respect to risks, income matters and race matters, but race matters more than income. To get the most "bang for the buck" on health impacts, focus on areas where high impact meets high inequity.**

Presentation Summary

Professor Marshall described an approach to reducing health risks from PM involving combined analysis of sources of emissions, concentrations at locations, levels of exposure to different sources of emissions, and racial and income disparities affecting environmental justice.

Many sources of PM. $PM_{2.5}$ comes from many sources, and not only from primary emissions but also through formation of $PM_{2.5}$ in the atmosphere from other compounds. No one single source is dominant. At the national level, several sources make up a substantial fraction of emissions, including fuel combustion, agriculture, road dust, and residential wood burning. However, there are many other meaningful contributors and therefore tackling $PM_{2.5}$ will require multiple strategies.

Intake fraction in California. When the levels of emissions from different sources are combined with the percentage of those emissions that are inhaled, relative contributions to exposure can more clearly be seen. In California, industrial emissions and on-road mobile sources are particularly high contributors to $PM_{2.5}$ exposure. Importantly, this conceptualization makes clear that emissions reductions are not all equal in impact. For example, reducing one ton of emissions from on-road mobile sources will have greater impact than reducing one ton of emissions from industrial sources because the former category has a higher intake fraction.

Race and income disparities. In California, white people and wealthier people are least exposed to pollution, and the racial difference is more predictive than the income difference. Looking at patterns of consumption, it is also evident that white people are the greatest consumers of the products of polluting activities despite being the least exposed to the resulting pollution.

Mobile measurements and low-emission zones. Dr. Marshall described mobile PM measurement technology as "really promising" for identifying local pollution hotspots and pointed to Google and Aclima as innovators. He also described the policy tool of "low-emission zones" that have been used around the world, although not yet in the U.S., to reduce risks for

vulnerable populations subjected to high PM concentrations. Even if some polluting activity relocates outside the zone, positive health outcomes can still be achieved with this strategy.

Advisory Council Q&A with Panelist

How much pollution comes from local sources? Council Member Long inquired how much of the contaminant load in West Oakland (depicted in the panelist's slide showing the results of mobile measurement) could be attributed to local versus regional sources. The panelist replied that the study did not investigate sources and deferred to Phil Martien, the final presenting panelist, to address the question of local versus regional contamination affecting West Oakland. (Dr. Martien's presentation revealed that the majority of $PM_{2.5}$ in West Oakland comes from regional sources; see Slide 198.)

Air District authority. In response to the panelist's question about the Air District's powers, Council Member Borenstein clarified that the Air District regulates stationary but not mobile sources and does not have the power to impose prices or taxes. Although the Air District does impose fines on a limited basis, these can only recover the costs of doing business, and emitters are not required to assume the costs of pollution below the standard. He went on to advocate for the Air District to "lobby Sacramento" for the authority to impose prices to help overcome a situation he described as "trying to make policy with one arm tied behind our back."

Other beneficiaries of polluting activities. Referring to the panelist's analysis of the drivers of pollution, which focused on consumption, Council Member Borenstein commented that additional beneficiaries of polluting activities should be considered: shareholders and workers.

Review of the National Ambient Air Quality Standards for Particulate Matter: Overview of the Draft Policy Assessment

Scott Jenkins
Project Lead, EPA review of National Ambient Air Quality Standards for PM
Senior Environmental Health Scientist, Office of Air Quality Planning and Standards, EPA

Main takeaways	**New studies available since the previous NAAQS review strengthen evidence of serious $PM_{2.5}$ health effects, including premature death, and add additional health concerns. Available scientific information calls into question the adequacy of the public health protection afforded by current standards. Risk assessment results show that reducing PM to alternative standard levels below the current standards would achieve significant additional health benefits, including thousands of lives spared per year in the U.S. Alternatively, retaining the current standards would require placing "little weight" on that information.**

Presentation Summary

Dr. Jenkins presented an overview of the approach and conclusions of the EPA's Draft PM Policy Assessment completed in response to the agency's Draft PM Integrated Science Assessment. He explained that the PM Policy Assessment is intended to serve as a bridge between science and rulemaking, which is expected to take place by the end of 2020. The assessment included an argument for revising the annual $PM_{2.5}$ standard downward based on the science, as well as a discussion of how retaining the current standard could be justified by placing little weight on the epidemiological evidence and risk assessment and greater weight on the uncertainties and limitations of the data.

Focus on "typical" exposures. The NAAQS review process focuses on exposures that represent the middle of the U.S. air quality distribution curve, rather than its extremes. In most U.S. locations, the annual standard is the controlling standard. Epidemiological data is not very informative with respect to the impact of 24-hour exposures on the upper end of the concentration distribution curve, and sub-daily (2-hour) controlled human exposure studies correspond to concentrations considered to be outside the typical distribution curve. The implication of this focus is that the review does not inform analysis of conditions analogous to those occurring during California wildfires.

Pseudo-design values and hybrid modeling. The review examined health effects seen in areas for which PM monitoring data could be used to calculate whether the area's air quality would have met the current standards. This "pseudo-design value" approach approximated the design value statistics used to describe air quality relative to the NAAQS. The review also examined

hybrid modeling studies that incorporated not only air quality monitoring but also a range of other data including satellite imagery and land use and transportation information.

Risk Assessment. The risk assessment considered likely mortality outcomes if national air quality was to "just meet" the current 12 µg/m^3 standard in comparison to "just meeting" 11, 10, and 9 µg/m^3. Although estimates differed according to the study being used and whether a primary or secondary PM-based modeling approach was employed, the overall implication was that thousands of lives would be spared at lower concentrations.

Conclusions. The Draft PM Policy Assessment states that "The available scientific information can reasonably be viewed as calling into question the adequacy of the public health protection afforded by the current annual and 24-hour primary $PM_{2.5}$ standards." This conclusion relies on the long-standing body of health evidence, strengthened in the latest review, and risk assessments indicating that current standards allow for thousands of $PM_{2.5}$-associated deaths per year at concentrations above 10 µg/m^3. However, the assessment also states that a conclusion that current standards are sufficient could be reached if very little weight is placed on the large body of epidemiological evidence, particularly the newly available studies regarding lower concentrations, and more weight is placed on uncertainties in the literature.

Advisory Council Q&A with Panelist

Wildfires excluding Bay Area from risk assessment. Chair Hayes asked for clarification on why the Bay Area was not included in the risk assessment. The panelist responded that the assessment aimed to simulate impact from anthropogenic sources, so the focus was on areas for which that adjustment could reliably be done using available data. The implication appeared to be that it was difficult to disentangle wildfire effects from anthropogenic effects.

Lessons for areas controlled by 24-hour standard? Given that the focus of the Draft PM Policy Assessment was on areas in which the annual standard is controlling, Chair Hayes asked what the Air District, which experiences 24-hour concentrations well above the standard during wildfires, should take away from the analysis. The panelist acknowledged that the epidemiology driving the assessment is focused on the middle of the air quality distribution and does not offer many insights for areas experiencing very high 24-hour and sub-daily concentrations.

Deaths from air pollution. Referring to Slide 155, Chair Hayes asked how the review process determines acceptable risk in terms of $PM_{2.5}$-associated deaths. The panelist responded that the estimates of $PM_{2.5}$-related deaths are not meant to be read as absolute numbers but rather used as a basis for comparison between outcomes at different concentration levels to indicate the magnitude of public health impact. He further noted that risk assessments have not historically been the drivers of decisions regarding NAAQS. Council Member Solomon asked if lower concentrations had also been considered in the risk assessment. The panelist replied that they had, and that estimated deaths are reduced by 10-15% for each 1 µg/m^3 reduction.

PM thresholds? Council Member Borenstein asked if the panelist had seen any evidence of a PM threshold. The panelist replied that he had not. However, he explained that there may be thresholds for individuals that cannot be seen in population-level studies.

Targeting Particulate Matter:
West Oakland Community Emissions Reduction Program

Phil Martien
Director, Assessment, Inventory, & Modeling, Bay Area Air Quality Management District
Project Lead, Technical Assessment of AB 617 West Oakland Community Action Plan

Main takeaways	**In response to California's AB 617 and in collaboration with communities, the Bay Area Air Quality Management District is implementing community-specific emissions reductions programs. The West Oakland plan demonstrates how hyperlocal modeling can be accomplished, but other agencies will also need to act in order to reach emissions reduction targets.**

Presentation Summary

Dr. Martien described the analysis conducted for the recently completed West Oakland Community Action Plan, the first in a series of community emissions reduction programs that the Air District is developing in response to California's AB 617 legislation.

Response to AB 617. California's Assembly Bill 617 mandates a statewide program to address long-standing air pollution concerns in disadvantaged communities. The Air District has committed to work collaboratively with disadvantaged communities experiencing disproportionately high levels of air pollution. The first year of implementation focused on Richmond and West Oakland; Richmond requires more measurements to be collected, but West Oakland had a large amount of data and was able to launch directly into planning an emissions reduction program. Beginning in year two, Air District efforts will expand to six more communities: Vallejo, the Pittsburg-Bay Point Area, Eastern San Francisco, the East Oakland-San Leandro Area, Tri-Valley, and San Jose.

Approach to West Oakland. West Oakland was chosen as the first implementation site both because its population experiences high socioeconomic burdens alongside low air quality and because West Oakland has a well-established and experienced community group, the West Oakland Environmental Indicators Project, that was able to guide the process in collaboration with the Air District. The study employed a hybrid modeling approach that first accounted for pollution originating outside the area in order to then zero in on local sources. In response to community requests, the study took a hyperlocal approach, modeling block-by-block exposures. Seven local impact zones were identified using data from specially equipped Google Street View vehicles. Sources modeled comprised the Port of Oakland, railyards and trains, vehicles on freeways and streets, truck-related businesses, and permitted stationary sources.

Results. Although the Port of Oakland was the primary contributor to diesel PM emissions, $PM_{2.5}$ showed a more distributed source allocation, with highway, street, port, and permitted sources all contributing significantly to $PM_{2.5}$ levels. However, approximately 34% of $PM_{2.5}$ came

from sources not included in the model, such as construction, restaurants, and residential wood burning. For each zone, the proportional contributions of the different sources were calculated, with different allocations evident for each zone. For example, 60% of modeled $PM_{2.5}$ could be attributed to street traffic in Zone 3, whereas street traffic made up only 28% of $PM_{2.5}$ emissions in Zones 1 and 2. Disparate exposure levels were seen within the studied West Oakland zones: the cleanest blocks are experiencing on average 3 $\mu g/m^3$ lower PM concentrations than the most polluted blocks.

Action priorities. The West Oakland Community Action Plan established the goal of bringing all zones to average levels for the area by 2025 and to the level of today's cleanest residential West Oakland neighborhood by 2030. However, it is important to note that most of the pollution experienced in West Oakland comes from regional sources outside the West Oakland local area, and most of the local pollution sources are outside the Air District's jurisdiction. That said, priorities for decreasing exposures from local sources center on addressing sources with higher shares of modeled impact, which include heavy-duty trucks and harbor craft for diesel PM and road dust and passenger vehicles for $PM_{2.5}$.

Advisory Council Q&A with Panelist

West Oakland levels in comparison to other District areas. Council Member Rudolph asked how the "average" and "cleanest" levels in West Oakland that were set as targets compare to air pollution levels elsewhere in the Air District. The panelist responded that he does not have that information because other areas have not yet been assessed. However, he asserted that differences in pollution levels between West Oakland other parts of the Air District are likely to be driven by local impacts, so addressing disparities within the Air District can be accomplished by considering local pollution sources.

Electric vehicles and road dust. Council Member Rudolph pointed out that if road dust is a significant concern in terms of $PM_{2.5}$ exposure, then solutions like electric vehicles will not address that problem. The panelist agreed.

Capturing unrecorded emissions. Council Member Rudolph asked whether further analysis would be conducted to better understand the $PM_{2.5}$ contributors that were not accounted for in the study. The panelist indicated that expanding the list of modeled sources was among the "homework activities" for the Air District team developing further AB 617 action plans.

Translating findings into action. Council Member Long asked for clarification on how the information presented would be translated into concrete actions to improve air quality in West Oakland. The panelist acknowledged the challenge of the Air District's limited jurisdiction and asserted that the West Oakland community had a "realistic perspective" on what can be done. He described the West Oakland Community Action Plan (which calls for the implementation of strategies by the City of Oakland, Port of Oakland, Caltrans, CARB, PG&E, and others in addition to the Air District) as "a starting point."

PM Exposure and Risks: Discussion Summary

Because the event was running long and Advisory Council members had addressed their questions to the individual panelists, the discussion between the Advisory Council and the afternoon panel was brief.

Margin of safety. Vice Chair Kleinman asked for clarification on whether the risk assessment within the Draft PM Policy Assessment considered margin of safety for particulate matter. Dr. Jenkins responded that the risk assessment does not address margin of safety because the concept of safety rests solely within the judgement of the EPA Administrator.

Public Comment

Public comment was taken during two designated periods during the event. A list of the commenters during those periods follows the summary. Questions were also addressed to the lunchtime keynote speaker, former EPA Administrator Gina McCarthy.

Comment Summary

The general sentiment expressed by many commenters was, "We need action, not more discussion." Several people spoke about their personal experiences with toxic emissions in their neighborhoods. The disproportionate impact of air pollution on disadvantaged communities is a central point of focus.

Additional themes that emerged in public comment:

Physicians. A group of physicians expressed their position that they are not able to protect the health of their patients due to air pollution, particularly children with asthma. They emphasized the return on investment from improving air quality.

African American communities. Two attendees who addressed Gina McCarthy during her keynote speech focused on the challenges of African American communities in the Air District relative to cumulative impacts of air pollution problems and the need for education, training, and investment in environmental health.

Refineries. Several speakers expressed concerns about refineries in the Air District, both with respect to air pollution and the need to reduce or eliminate reliance on fossil fuels.

Mobile-source increases from stationary permits. A speaker from East Oakland highlighted air quality challenges from a local crematorium, not only from its direct emissions but also from diesel trucks making frequent deliveries.

Climate change. Concerns about climate change aspects of air pollution were emphasized in addition to the need to address immediate health issues.

Community representation. The suggestion was made to form a community advisory board for the Air District "with teeth," i.e., with the power to make and enact decisions.

List of commenters

PUBLIC COMMENT ON AGENDA MATTERS (ITEM 3)
Dr. Ashley McClure, California Climate Health Now
Sarah Schear, California Climate Health Now

PUBLIC COMMENT ON NON-AGENDA MATTERS (ITEM 7)
Katherine Funes, Rose Foundation for the Communities and the Environment
Jed Holtzman, 350 Bay Area
Jan Warren, Interfaith Climate Action Network of Contra Costa County
Dr. Amanda Millstein, California Climate Health Now
Dr. Cynthia Mahoney, California Climate Health Now
Sarah Schear, California Climate Health Now
Maureen Brennan, Rodeo citizen
Charles Davidson, Sunflower Alliance
Ken Szutu, Citizen's Air Monitoring Network
Margie Lewis, Communities for a Better Environment
Steve Nadel, Sunflower Alliance

Advisory Council Deliberation

The symposium concluded with the Advisory Council's deliberation regarding the implications of the information presented. The Advisory Council arrived at the following Sense of the Advisory Council statement:

> **The current standard is not adequately health protective. Further reductions in particulate matter will realize additional health benefits. We ask the Air District staff to bring forward with urgency options within the legal authority of the Air District that would limit PM exposure, especially in high-risk communities.**

Council Member Borenstein reflected the sentiment of the Advisory Council in stating, "We need more science, and we should act."

Additionally, Advisory Council members expressed interest in further exploring the potential for:

Treating PM as a toxic. Council Member Solomon stated that the lack of evidence for a threshold for PM health effects argues for treatment of PM as a linear, non-threshold toxic in the same manner as other toxic air contaminants and carcinogens.

Monitoring ultrafine particles. Council Member Solomon indicated support for continuing monitoring of ultrafine particles in the Bay Area or increasing monitoring if the costs are not unreasonable. The Air District's Deputy Air Pollution Control Officer Greg Nudd proposed that the Air District present to the Advisory Council regarding the UFP monitoring that is already occurring in order to better inform the Advisory Council's recommendations.

Encouraging the State of California to adopt stricter PM standards. Acknowledging that the District does not have the authority to set ambient air standards, Vice Chair Kleinman suggested that those present in the room should encourage the State to adopt stricter PM standards.

Ensuring local permits are consistent with PM standards supported by the science. Vice Chair Kleinman stated that because local permits and emission requirements for stationary sources are the specific purview of the Air District, the Advisory Council should focus on advising the Board on how the Air District could make those determinations consistent with improved ambient air standards.

Disaggregating solutions with climate co-benefits, solutions unrelated to climate strategies, and emergencies. Council Member Long argued for separately approaching three different categories of strategies for addressing PM: 1) strategies that reduce particulate matter as a co-benefit of addressing climate change, such as making engines more efficient and decarbonizing electricity; 2) strategies regarding issues such as road dust that are independent of climate

action (given that more efficient or electric cars still produce brake, tire, and road dust); and 3) emergencies including wildfires and explosions at permitted sites.

Bang for the buck. Council Member Long stressed the need to identify strategies with the greatest potential for impact and to track the outcomes of the strategies that are implemented.

Air District Implementation Plan. Vice Chair Kleinman stated the need for an Air District Implementation Plan in accordance with cleaner air standards. Chair Hayes expressed interest in the idea of an Air District Implementation Plan but stated that he was not yet ready to endorse the strategy and needed to gain a better understanding of what it would entail.

Next Steps

Three primary action items emerged from the first PM symposium:

1. **Air District delivery of presentations** to the Advisory Council on the Air District's current activities and capabilities to monitor ultrafine particles and to address PM exposures;
2. **Advisory Council discussion and deliberation** on these current and potential activities in light of the information presented at the October 28 symposium and summarized in this document; and
3. **Planning for a second symposium** for Spring 2020 to focus on community and other stakeholder input and engagement concerning PM exposures and health risks.

The Advisory Council will reconvene on **December 9, 2019**.

During that meeting, in response to the Advisory Council's requests, the Air District will present on its current activities to reduce PM exposures, including monitoring of ultrafine particles. It will also discuss additional "options within the legal authority of the Air District that would limit PM exposure, especially in high-risk communities," in accordance with the Sense of the Advisory Council, in order to inform the Advisory Council's advice to the Board.

The Advisory Council is expected to receive and comment on this symposium summary document during the December 9 meeting.

Planning for the Spring 2020 event continues with input from community representatives and other stakeholders.

Particulate Matter:
Spotlight on Health Protection

Call to Order
Pledge of Allegiance
Public Comment
Approval of Minutes

Stan Hayes

Particulate Matter:
Spotlight on Health Protection

Welcome Remarks

Jack Broadbent

Particulate Matter:
Spotlight on Health Protection

Introduction

Jeff McKay

Particulate Matter:
Spotlight on Health Protection

PM Symposium Series




Health Effects

Jason Sacks, M.P.H.

- Senior Epidemiologist in the Center for Public Health & Environmental Assessment within U.S. EPA's Office of Research and Development
- Assessment lead for the Particulate Matter Integrated Science Assessment
- Key leadership roles in synthesizing the health effects evidence of air pollution for various National Ambient Air Quality Standards reviews
- International training on U.S. EPA's Environmental Benefits Mapping and Analysis Program – Community Edition
- M.P.H. from Johns Hopkins University in 2003

Current State of Particulate Matter Science: Particulate Matter Integrated Science Assessment (PM ISA) (Working Draft Conclusions)

Particulate Matter: Spotlight on Health Protection

Bay Area Air Quality Management District

Jason Sacks
Center for Public Health and Environmental Assessment
Office of Research and Development
U.S. Environmental Protection Agency

October 28, 2019

C40

Disclaimer

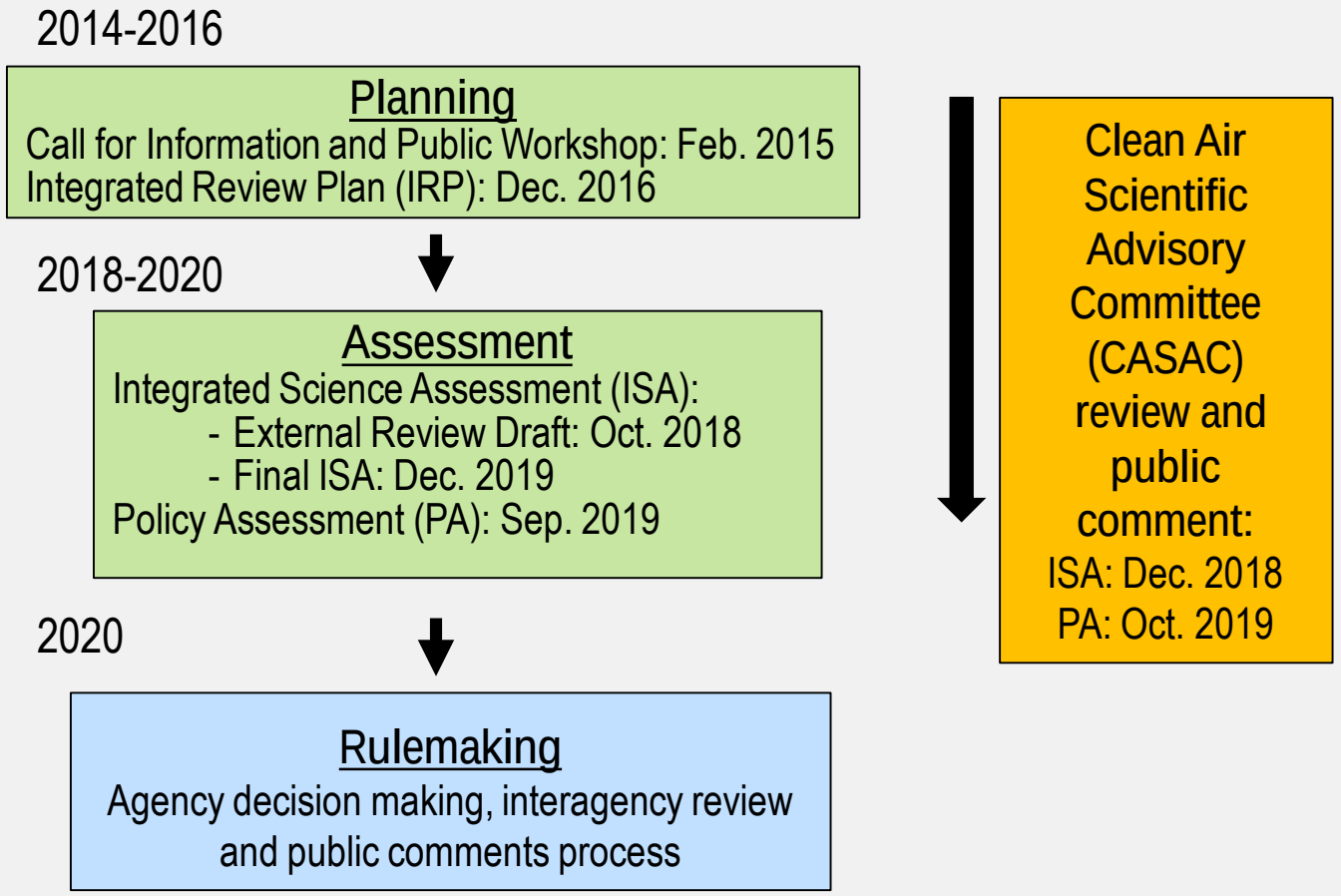
This presentation is based on information provided in the external review draft Integrated Science Assessment for Particulate Matter (PM ISA) as well as ongoing revisions to the PM ISA based on comments provided by the public and Clean Air Scientific Advisory Committee (CASAC). It has not been formally disseminated by EPA. It does not represent and should not be construed to represent any Agency determination or policy. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Outline

- PM NAAQS Milestones
- PM ISA
  - Weight-of-Evidence Evaluation
  - Scope
  - Ultrafine Particles (UFPs)
  - Causality Determinations: Health Effects
    - Likely to be Causal
    - $PM_{2.5}$ Sources and Components
    - Populations/Lifestages at Increased Risk
  - Next Steps

Overview of the Process for Reviewing the PM NAAQS

- IRP: Planned approach, schedule
- ISA: Assesses the available scientific information on public health and welfare effects; provides the science foundation for the review
- PA: Transparent analysis of the adequacy of the current standards and, as appropriate, potential alternatives



Note: This NAAQS Review Process was originally outlined in Administrator Pruitt's May 9, 2018 "Back to Basics" Memo.

Weight-of-Evidence Approach for Causality Determinations for Health and Welfare Effects

- Provides transparency through structured framework
- Developed and applied in ISAs for all criteria pollutants
- Emphasizes synthesis of evidence across scientific disciplines (e.g., controlled human exposure, epidemiologic, and toxicological studies)
- Five categories based on overall weight-of-evidence:
  - Causal relationship
  - Likely to be causal relationship
  - Suggestive of, but not sufficient to infer, a causal relationship
  - Inadequate to infer the presence or absence of a causal relationship
  - Not likely to be a causal relationship
- ISA Preamble describes this framework
  - Preamble is now stand-alone document (http://www.epa.gov/isa)
- CASAC extensively reviewed the Agency's causal framework in the process of reviewing ISAs from 2008 – 2015; its use was supported in all ISAs

Scope

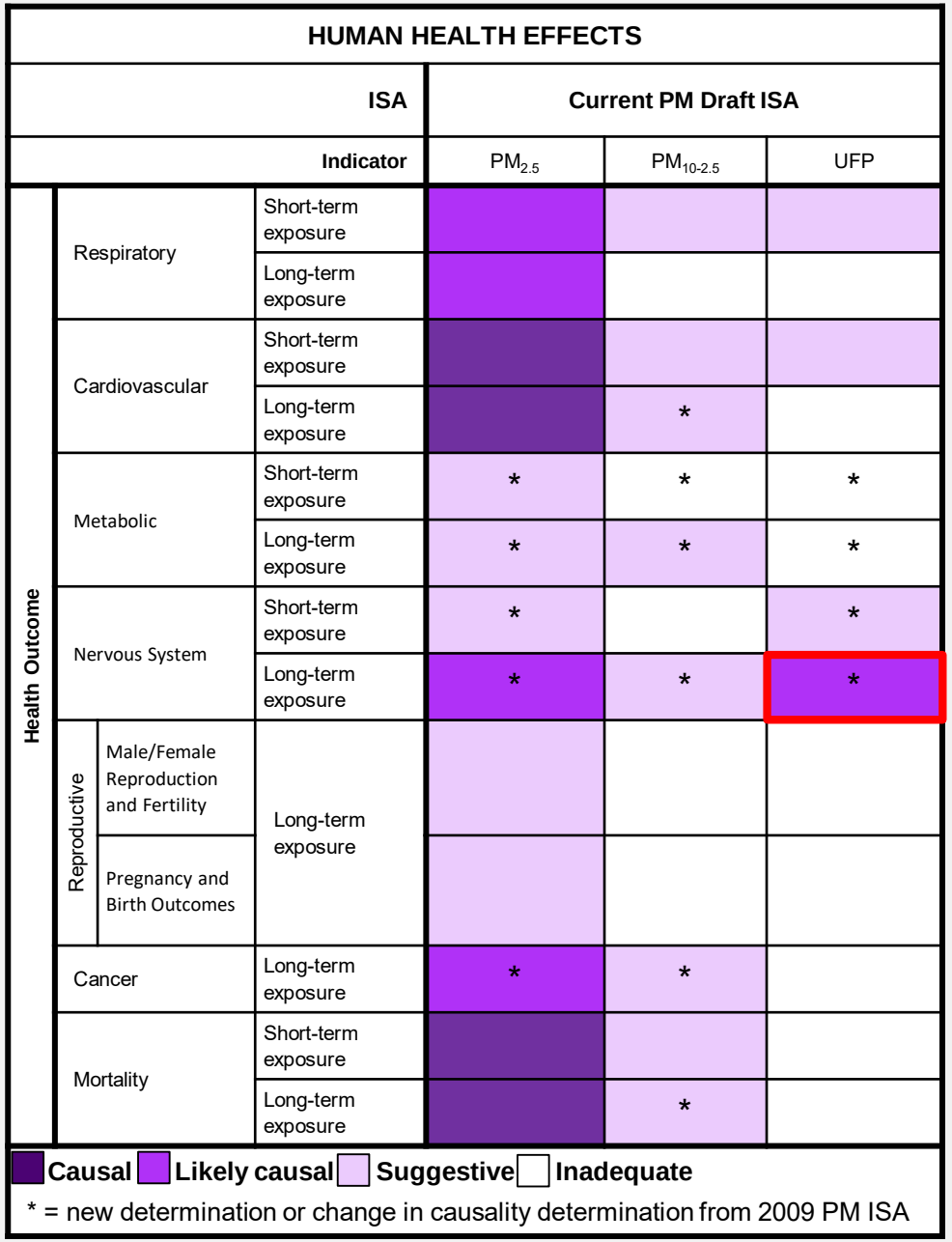
- **Scope:** The ISA is tasked with answering the question "Is there an independent effect of PM on health and welfare at relevant ambient concentrations?"
  - Health Effects
    - Studies will be considered if they include a composite measure of PM (e.g., $PM_{2.5}$ mass, $PM_{10-2.5}$ mass, ultrafine particle (UFP) number)
      - Studies of source-based exposures that contain PM (e.g., diesel exhaust, wood smoke, etc.) if they have a composite measure of PM and examine effects with and without particle trap to assess the particle effect
      - Studies of components of PM if they include a composite measure of PM to relate toxicity of component(s) to current indicator
    - Studies will be considered if PM exposures are relevant to ambient concentrations (< 2 mg/m^3; 1 to 2 orders of magnitude above ambient concentrations)

Ultrafine Particles (UFPs)

- Ultrafine particles are generally considered to be PM with a diameter less than or equal to 0.1 µm (100 nm)
- Uncertainties:
  - Highly variable concentration in space and over time due to physical and chemical processing in the atmosphere
    - UFP concentrations are highest in urban areas and during rush hour, and are highly episodic during winter
  - Lack of U.S. monitoring network and limited data on spatial and temporal UFP concentrations
  - UFP measured using multiple methods, varying in the size ranges examined - some capturing multiple size ranges below 100 nm, while others can include sizes above 100 nm
    - Contributed to difficulty in evaluating evidence within and across epidemiologic and experimental studies

Draft PM ISA Health Effects: Causality Determinations

Table 1-5. Summary of causality determinations for health effect categories for the draft PM ISA.



HUMAN HEALTH EFFECTS					
		ISA	Current PM Draft ISA		
		Indicator	$PM_{2.5}$	$PM_{10-2.5}$	UFP
Health Outcome	Respiratory	Short-term exposure			
		Long-term exposure			
	Cardiovascular	Short-term exposure			
		Long-term exposure		*	
	Metabolic	Short-term exposure	*	*	*
		Long-term exposure	*	*	*
	Nervous System	Short-term exposure	*		*
		Long-term exposure	*	*	*
	Reproductive: Male/Female Reproduction and Fertility	Long-term exposure			
	Reproductive: Pregnancy and Birth Outcomes	Long-term exposure			
	Cancer	Long-term exposure	*	*	
	Mortality	Short-term exposure			
		Long-term exposure		*	

Causal | Likely causal | Suggestive | Inadequate

* = new determination or change in causality determination from 2009 PM ISA

Respiratory Effects

Recent evidence supports the conclusions of the 2009 PM ISA, and continues to support a likely to be causal relationship between short-term $PM_{2.5}$ exposure and respiratory effects

- Epidemiologic evidence:
  - Consistent evidence for asthma exacerbation in children and COPD exacerbation in adults; respiratory mortality.
- Experimental evidence:
  - Animal models of asthma and COPD demonstrate worsening of allergic airway disease and/or subclinical effects
- Remaining Uncertainties:
  - Lack of coherence between epidemiologic and animal toxicological evidence because most effects demonstrated in healthy animals
  - Minimal evidence from controlled human exposure studies for respiratory effects
  - Limited assessment of potential copollutant confounding

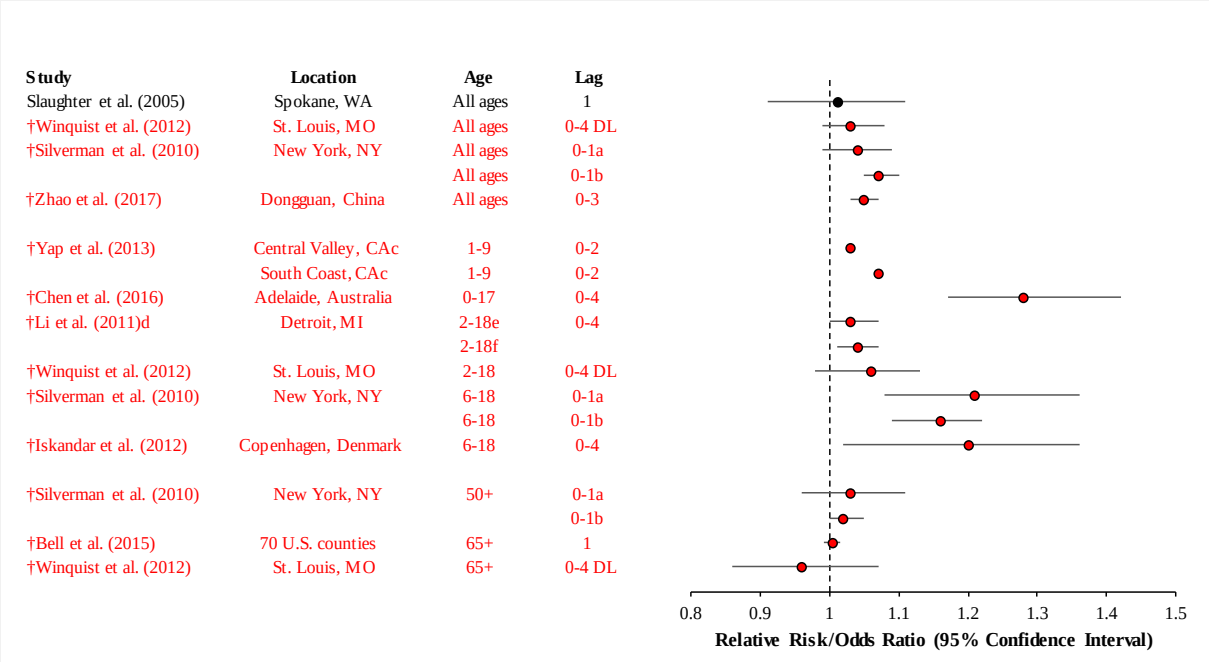


Figure 5-2. Summary of associations between short-term $PM_{2.5}$ exposures and asthma hospital admissions for a 10 µg/m³ increase in 24-hour average $PM_{2.5}$ concentrations.

Red = recent studies;
Black = U.S. study evaluated in the 2009 PM ISA

Respiratory Effects (cont.)

Recent evidence supports the conclusions of the 2009 PM ISA, and continues to support a likely to be causal relationship between long-term $PM_{2.5}$ exposure and respiratory effects

- Epidemiologic evidence:
  - Consistent changes in lung function and lung function growth
  - Increased asthma incidence, asthma prevalence and wheeze in children
  - Acceleration of lung function decline in adults
  - Improvements in lung function growth with declining $PM_{2.5}$ concentrations
  - Consistent evidence for increased risk of respiratory mortality
- Experimental evidence:
  - Impaired lung development and development of allergic airway disease
  - Biological plausibility for decrements in lung function growth in children and asthma development
- Remaining Uncertainties:
  - Limited evidence from animal toxicological studies
  - Limited assessment of potential copollutant confounding

Nervous System Effects

- Long-term $PM_{2.5}$ Exposure **(Likely to be Causal – NEW conclusion)**
  - Epidemiologic evidence:
    - Consistent evidence for cognitive decline/impairment and decreased brain volume
    - Limited evidence for neurodegeneration (e.g., Alzheimer's disease and dementia)
  - Experimental evidence:
    - Consistent evidence for inflammation, oxidative stress, morphologic changes, and neurodegeneration in multiple brain regions of adult animals
    - Limited evidence for early indicators of Alzheimer's disease, impaired learning/memory, altered behavior in adult animals, and morphologic changes during development
  - Remaining Uncertainties:
    - Challenge conducting epidemiologic studies of neurodegeneration because often a genetic component
    - Epidemiologic studies of neurodevelopmental effects limited due to the small number of studies, and uncertainty regarding critical exposure windows
    - Limited assessment of potential copollutant confounding

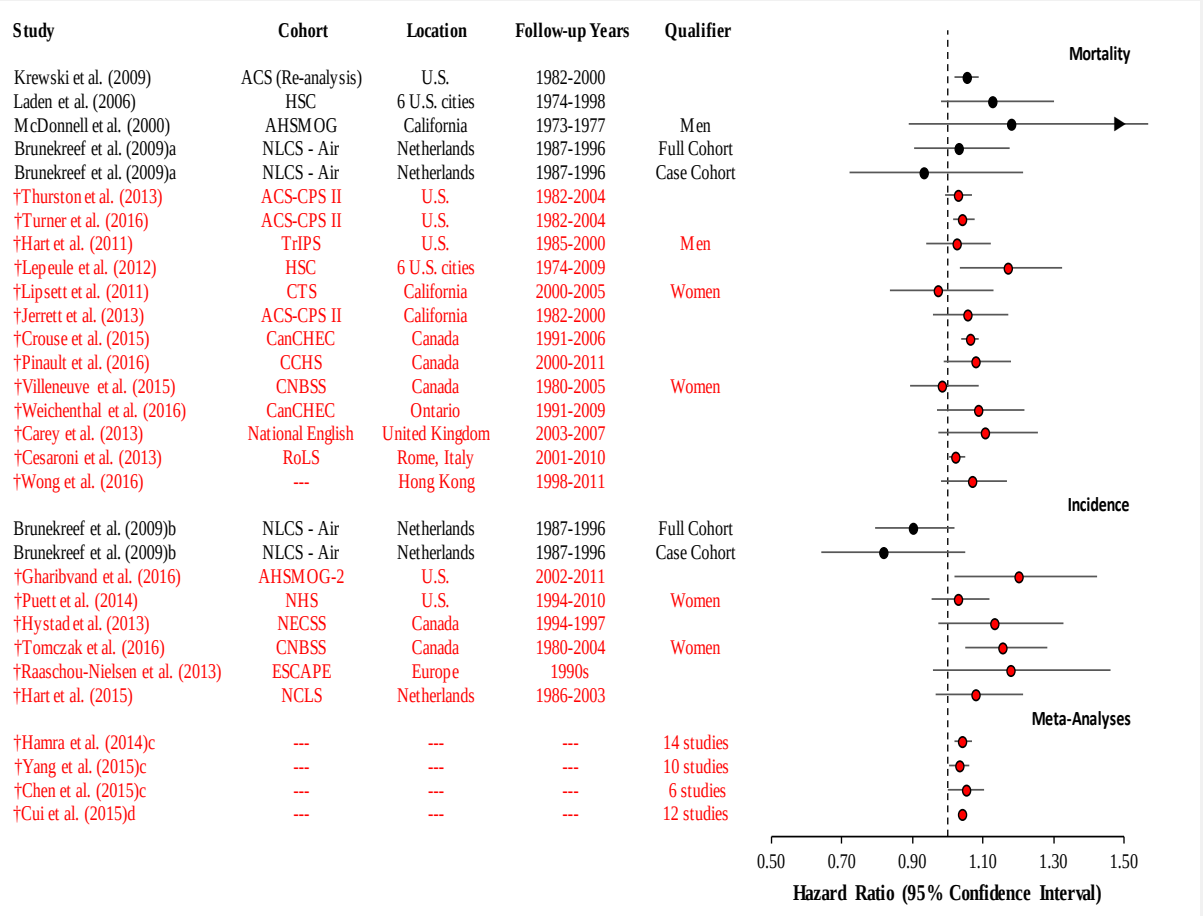
Nervous System Effects

- Long-term UFP Exposure **(Likely to be Causal – NEW conclusion)**
  - Epidemiologic evidence:
    - Limited evidence for effects on cognitive development in children
  - Experimental evidence:
    - Consistent evidence for inflammation, oxidative stress, and neurodegeneration in adult animals
    - Limited evidence of Alzheimer's disease pathology in a susceptible animal model
    - Strong evidence of developmental effects, mainly from one laboratory, for inflammation, morphologic changes including persistent ventriculomegaly, and behavioral effects following pre/postnatal exposure
  - Remaining Uncertainties:
    - Relative lack of epidemiologic studies
    - Inconsistency in size range of UFPs examined across disciplines
    - Spatial and temporal variability in UFP concentrations
    - Relative lack of UFP monitoring data
    - Long-term exposure to UFPs

Cancer

Long-term $PM_{2.5}$ Exposure (Likely to be Causal – NEW conclusion)

- Decades of research on whole PM exposures:
  - Genotoxicity
  - Epigenetic effects
  - Carcinogenic potential
  - Characteristics of carcinogens
- Experimental and epidemiologic studies examining $PM_{2.5}$ support:
  - Genotoxicity
  - Epigenetic effects
  - Carcinogenic potential
  - Characteristics of carcinogens
- Epidemiologic evidence:
  - Lung cancer incidence and mortality
- Remaining Uncertainties:
  - Inconsistency in specific cancer-related biomarkers across disciplines
  - Limited assessment of copollutant confounding



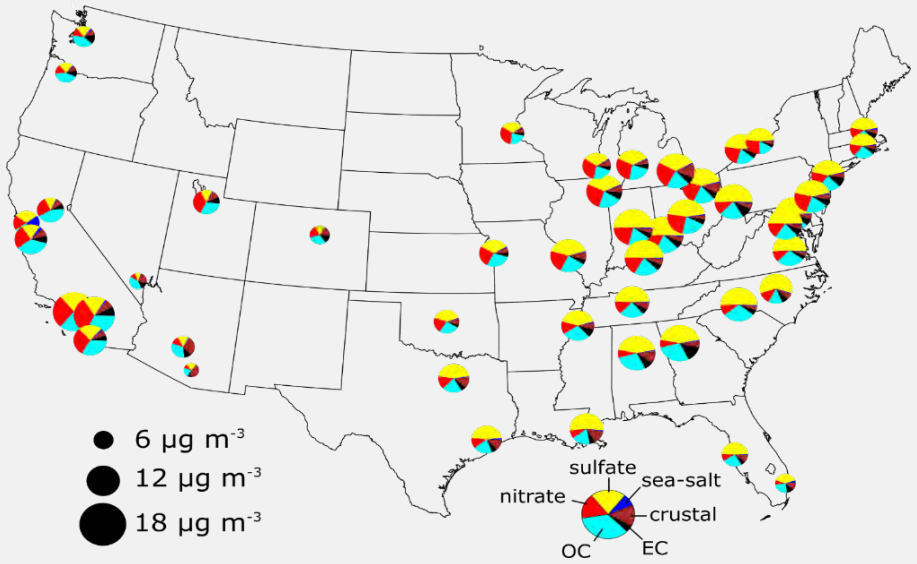
Note: Red = recent studies; Black = studies evaluated in the 2009 PM ISA

Figure 10-3. Summary of associations reported in previous and recent cohort studies that examined long-term $PM_{2.5}$ exposure and lung cancer mortality and incidence.

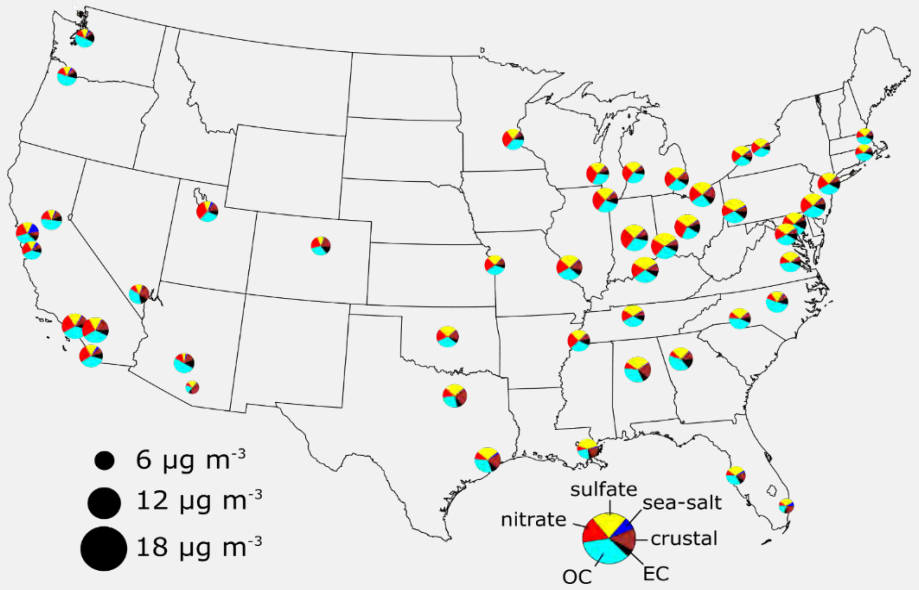
PM Components and Sources

- Conclusion:
  - Many $PM_{2.5}$ components and sources are associated with many health effects, and the evidence does not indicate that any one source or component is more strongly related with health effects than $PM_{2.5}$ mass
    - Evaluation of individual components, based largely on evidence from epidemiologic studies
    - Evaluation of sources limited to a smaller subset of studies
      - Across studies, consistent evidence for effects with various combustion-related sources (e.g., industrial activities, traffic, wildfires, biomass burning, etc.)

National Trend in $PM_{2.5}$ Component Concentrations



2003 - 2005



2013 - 2015

- 2003 - 2005: As % of total mass, sulfate higher in East; OC in West
- 2013 – 2015: Reduction in sulfate contribution in East; contributions similar to 2003 – 2005 in West
- Overall: Organic carbon has replaced sulfate as the most abundant component of $PM_{2.5}$ in many locations, specifically in the eastern U.S.

Example: $PM_{2.5}$ Components and Cardiovascular Effects

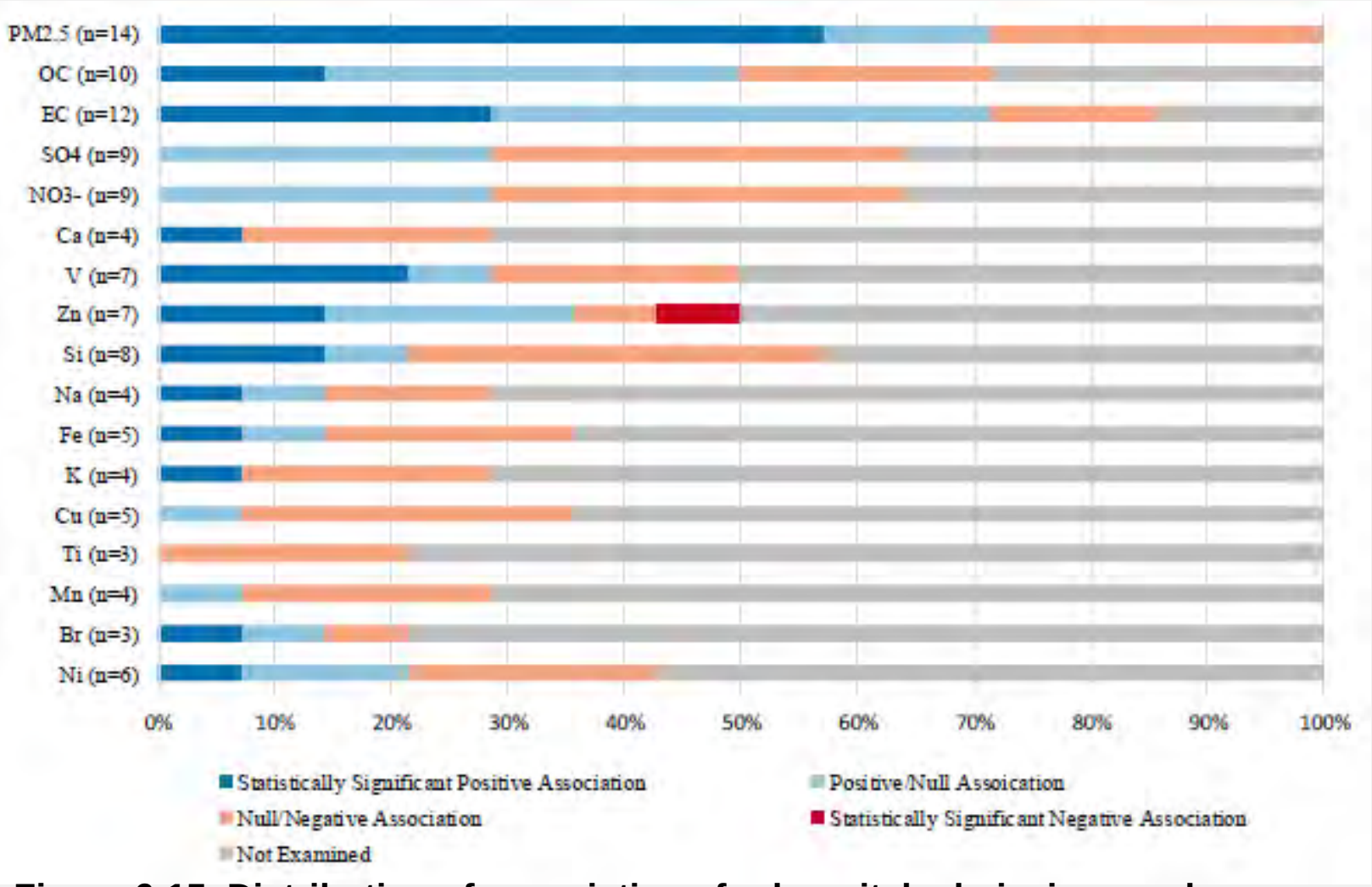


Figure 6-15. Distribution of associations for hospital admissions and emergency department visits for cardiovascular-related effects and short-term $PM_{2.5}$ and $PM_{2.5}$ components exposure.

Populations Potentially at Increased Risk of a PM-related Health Effect

- The NAAQS are intended to protect both the population as a whole and those potentially at increased risk for health effects in response to exposure to criteria air pollutants
  - *Are there specific populations and lifestages at increased risk of a PM-related health effect, compared to a reference population?*
- The ISA identified and evaluated evidence for factors that may increase the risk of $PM_{2.5}$-related health effects in a population or lifestage, classifying the evidence into four categories:
  - Adequate evidence; suggestive evidence; inadequate evidence; evidence of no effect
- Conclusions:
  - Adequate: children and nonwhite populations
  - Suggestive: pre-existing cardiovascular and respiratory disease, overweight/obese, genetic variants glutathione transferase pathways, low SES
  - Inadequate: pre-existing diabetes, older adults, residential location, sex, diet, and physical activity

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Supplemental Materials

Framework for Causality Determinations in the ISA

	Health Effects	Ecological and Other Welfare Effects
Causal relationship	Evidence is sufficient to conclude that there is a causal relationship with relevant pollutant exposures (e.g., doses or exposures generally within one to two orders of magnitude of recent concentrations). That is, the pollutant has been shown to result in health effects in studies in which chance, confounding, and other biases could be ruled out with reasonable confidence. For example: (1) controlled human exposure studies that demonstrate consistent effects, or (2) observational studies that cannot be explained by plausible alternatives and that are supported by other lines of evidence (e.g., animal studies or mode of action information). Generally, the determination is based on multiple high-quality studies conducted by multiple research groups.	Evidence is sufficient to conclude that there is a causal relationship with relevant pollutant exposures. That is, the pollutant has been shown to result in effects in studies in which chance, confounding, and other biases could be ruled out with reasonable confidence. Controlled exposure studies (laboratory studies) provide the strongest evidence for causality, but the scope of inference may be limited. Generally, the determination is based on multiple studies conducted by multiple research groups, and evidence that is considered sufficient to infer a causal relationship is usually obtained from the joint consideration of many lines of evidence that reinforce each other.
Likely to be a causal relationship	Evidence is sufficient to conclude that a causal relationship is likely to exist with relevant pollutant exposures. That is, the pollutant has been shown to result in health effects in studies where results are not explained by chance, confounding, and other biases, but uncertainties remain. For example: (1) observational studies show an association, but copollutant exposures are difficult to address and/or other lines of evidence (e.g., human exposure, animal, or mode of action information) are limited or inconsistent, or (2) animal toxicological evidence from multiple studies from different laboratories demonstrate effects, but limited or no human data are available. Generally, the determination is based on multiple high-quality studies.	Evidence is sufficient to conclude that there is a likely causal association with relevant pollutant exposures. That is, an association has been observed between the pollutant and the outcome in studies in which chance, confounding, and other biases are minimized but uncertainties remain. For example, field studies show a relationship, but suspected interacting factors [illegible] and other lines of evidence are limited or inconsistent. Generally, the determination is based on multiple studies by multiple research groups.
Suggestive of, but not sufficient to infer, a causal relationship	Evidence is suggestive of a causal relationship with relevant pollutant exposures but is limited, and chance, confounding, and other biases cannot be ruled out. For example: (1) when the body of evidence is relatively small, at least one high-quality epidemiologic study shows an association with a given health outcome and/or at least one high-quality study [illegible] effects relevant to humans in animal species, or (2) when the body of evidence is relatively large, evidence from studies of varying quality is generally supportive but not entirely consistent, and there may be coherence across lines of evidence (e.g., animal studies or mode of action information) to support the determination.	Evidence is suggestive of a causal relationship with relevant pollutant exposures, but chance, confounding, and other biases cannot be ruled out. For example, at least one high-quality study shows an effect, but the results of other studies are inconsistent.
Inadequate to infer a causal relationship	Evidence is inadequate to determine that a causal relationship exists with relevant pollutant exposures. The available studies are of insufficient quality, consistency, or statistical power to permit a conclusion regarding the presence or absence of an effect.	Evidence is inadequate to determine that a causal relationship exists with relevant pollutant exposures. The available studies are of insufficient quality, consistency, or statistical power to permit a conclusion regarding the presence or absence of an effect.
Not likely to be a causal relationship	Evidence indicates there is no causal relationship with relevant pollutant exposures. Several adequate studies, covering the full range of levels of exposure that human beings are known to encounter and considering at-risk populations and lifestages, are mutually consistent in failing to show an effect at any level of exposure.	Evidence indicates there is no causal relationship with relevant pollutant exposures. Several adequate studies examining relationships with relevant exposures are consistent in failing to show an effect at any level of exposure.

Multiple, high-quality studies
Rule out chance, confounding, and other biases with reasonable confidence

Multiple, high-quality studies
Important uncertainties remain

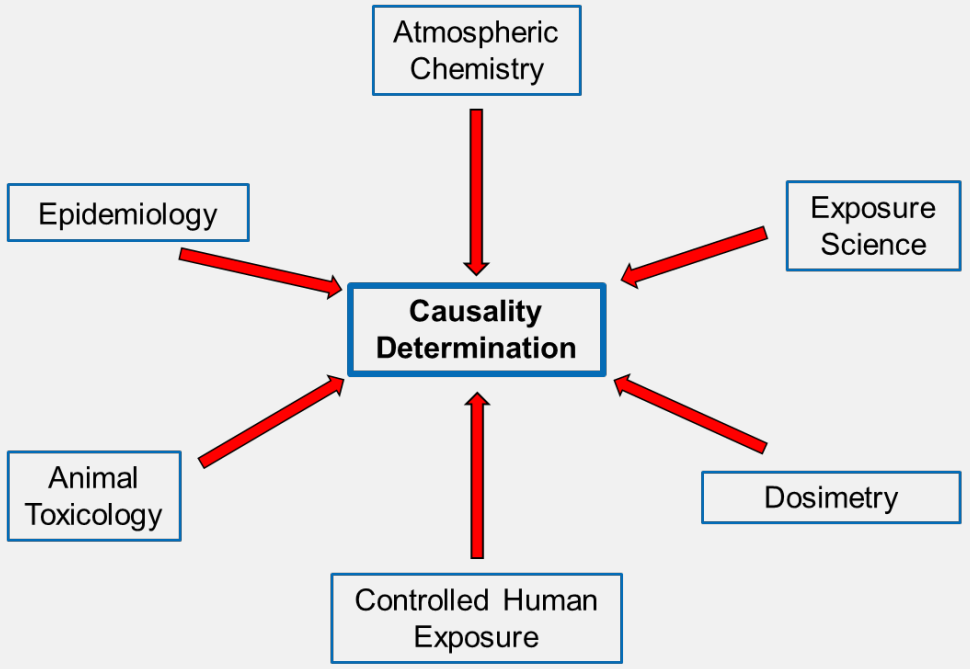
Evidence is suggestive but limited

Evidence is of insufficient quantity, quality, consistency, or statistical power

Multiple studies show no effect across exposure concentrations

Evaluation of the Scientific Evidence

- Organize relevant literature for broad outcome categories
- Evaluate studies, characterize results, extract relevant data
- Integrate evidence across disciplines for outcome categories
- Develop causality determinations using established framework
- Evaluate evidence for populations potentially at increased risk
- Consideration of evidence spans many scientific disciplines from source to effect:
  - Atmospheric chemistry
  - Exposure
  - Controlled human exposure studies
  - Epidemiologic studies
  - Animal toxicologic studies



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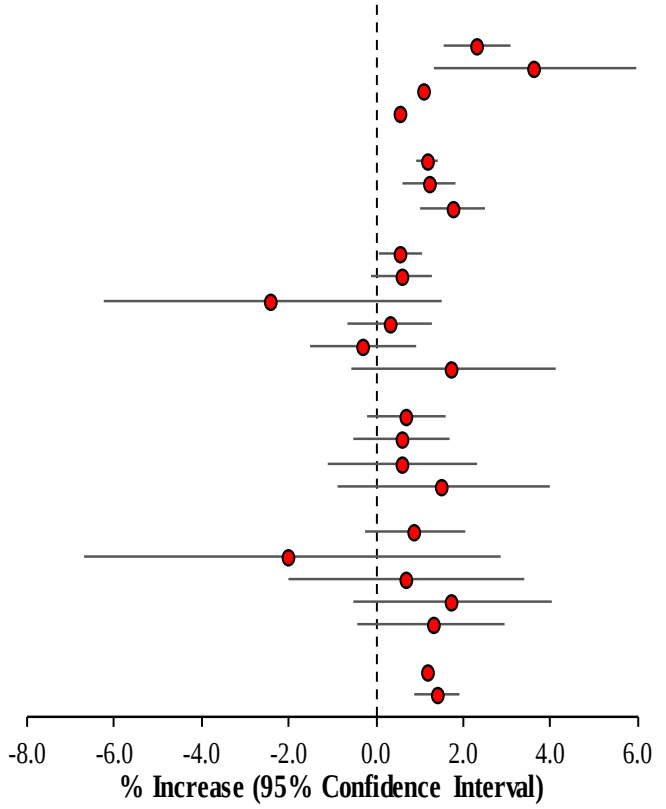
Cardiovascular Effects

A large body of recent evidence supports and extends the conclusions of the 2009 PM ISA that there is a causal relationship between short- and long-term $PM_{2.5}$ exposure and cardiovascular effects

Study	Location	Lag	Outcome
†Lee et al. (2015)a	3 Southeast states, U.S.	0-1	Cardiovascular CHF MI Stroke
†Dai et al. (2014)	75 U.S. cities	0-1	Cardiovascular MI Stroke
†Samoli et al. (2013) †Samoli et al. (2014)	10 European Med cities 10 European Med cities	0-1	Cardiovascular Cardiac CHF Cerebrovascular Acute Coronary Events Arrhythmias
†Pascal et al. (2014)	9 French cities	0-1	Cardiovascular Cardiac IHD Cerebrovascular
†Milojevic et al. (2014)	England and Wales	0-1	Cardiovascular CHF MI Stroke IHD
†Shah et al. (2015) †Wang et al. (2014)	Meta-analysis Meta-analysis	--- ---	Stroke Stroke



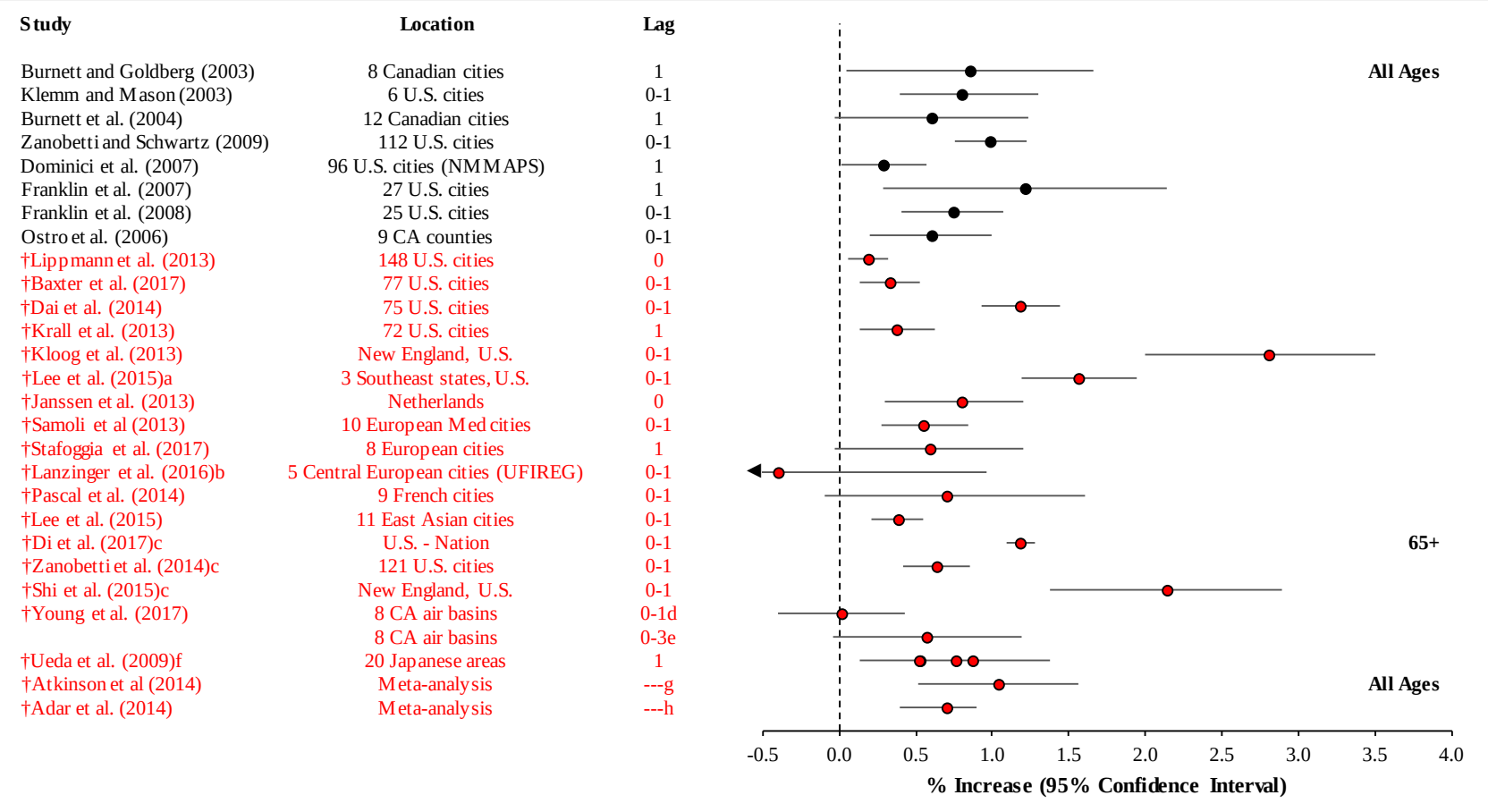
Note: Red = recent studies; Black = studies evaluated in the 2009 PM ISA

Figure 6-7. Percent increase in cause-specific cardiovascular mortality outcomes for a 10 µg/m³ increase in 24-hour average $PM_{2.5}$ concentrations observed in multicity studies and meta-analyses.

C61

Mortality – Short-term $PM_{2.5}$ Exposure

Recent evidence supports and extends the conclusions of the 2009 PM ISA that there is a causal relationship between short-term $PM_{2.5}$ exposure and mortality



Note: Red = recent multi-city studies; Black = multi-city studies evaluated in the 2009 PM ISA

Figure 11-1. Summary of associations between short-term $PM_{2.5}$ exposure and total (nonaccidental) mortality in multicity studies for a 10 μg/m³ increase in 24-hour average concentrations.

Mortality – Long-term $PM_{2.5}$ Exposure

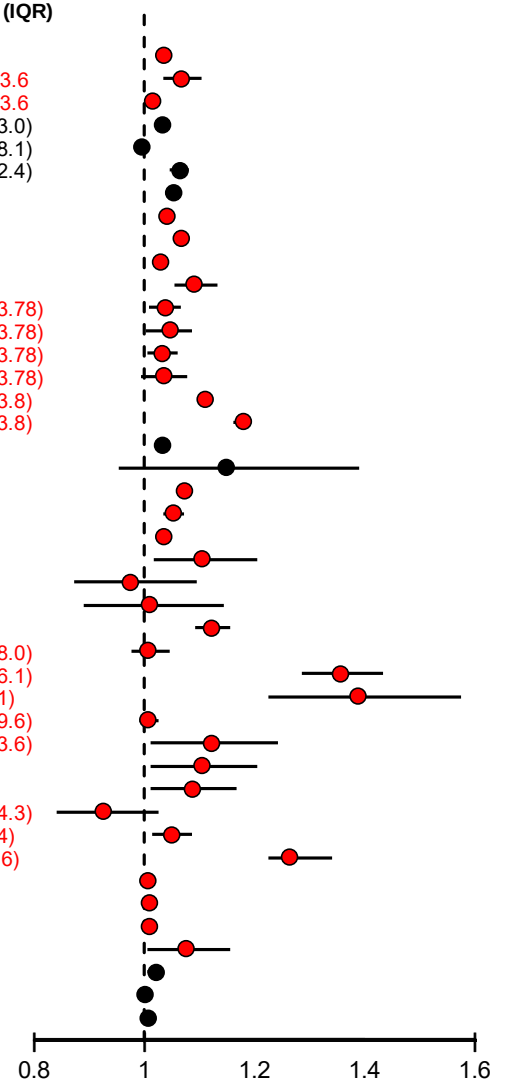
Recent evidence supports and extends the conclusions of the 2009 PM ISA that there is a causal relationship between long-term $PM_{2.5}$ exposure and mortality

Figure 11-18. Associations between long-term $PM_{2.5}$ and total (nonaccidental) mortality in recent North American cohorts.

Note: Associations are presented per 5 μg/m^3 increase in pollutant concentration.

Red = recent studies;
Black = studies evaluated in the 2009 PM ISA

Reference	Cohort	Notes	Years	Mean (IQR)
†Pope et al. 2014	ACS		1982-2004	12.6
†Lepeule et al. 2012	Harvard Six Cities		1974-2009	11.4-23.6
†Thurston et al. 2015	NIH-AARP		2000-2009	10.2-13.6
Zeger et al. 2008	MCAPS	Eastern	2000-2005	14.0 (3.0)
Zeger et al. 2008	MCAPS	Western	2000-2005	13.1 (8.1)
Zeger et al. 2008	MCAPS	Central	2000-2005	10.7 (2.4)
Eftim et al. 2008	ACS-Medicare		2000-2002	13.6
†Di et al. 2017	Medicare		2000-2012	11.5
†Di et al. 2017	Medicare	exp<12	2000-2012	11.5
†Di et al. 2017	Medicare	nearest monitor	2000-2012	11.5
†Kioumourtzoglou et al. 2016	Medicare		2000-2010	12
†Shi et al. 2015	Medicare	mutual adj	2003-2008	8.12 (3.78)
†Shi et al. 2015	Medicare	exp <10, mutual adj	2003-2008	8.12 (3.78)
†Shi et al. 2015	Medicare	no mutual adj	2003-2008	8.12 (3.78)
†Shi et al. 2015	Medicare	exp <10, no mutual adj	2003-2008	8.12 (3.78)
†Wang et al. 2017	Medicare		2000-2013	10.7 (3.8)
†Wang et al. 2017	Medicare	exp<12	2000-2013	10.7 (3.8)
Lipfert et al. 2006	Veterans Cohort		1997-2001	14.34
Goss et al. 2004	U.S. Cystic Fibrosis		1999-2000	13.7
†Crouse et al. 2012	CanCHEC	Satellite data	1991-2001	8.9
†Crouse et al. 2012	CanCHEC	Monitor data	1991-2001	11.2
†Crouse et al. 2015	CanCHEC		1991-2006	8.9
†Chen et al. 2016	EFFECT		1999-2011	10.7
†Weichenthal et al. 2014	Ag Health		1993-2009	8.84
†Weichenthal et al. 2014	Ag Health	more precise exp	1993-2009	8.84
†Pinault et al. 2016	CCHS		1998-2011	6.3
†Lipsett et al. 2011	CA Teachers		2000-2005	15.6 (8.0)
†Ostro et al. 2010	CA Teachers	within 30 km	2002-2007	17.5 (6.1)
†Ostro et al. 2010	CA Teachers	within 8 km	2002-2007	17 (6.1)
†Ostro et al. 2015	CA Teachers		2001-2007	17.9 (9.6)
†Puett et al. 2009	Nurses Health		1992-2002	13.9 (3.6)
†Hart et al. 2015	Nurses Health	nearest monitor	2000-2006	12.7
†Hart et al. 2015	Nurses Health	spatio-temp. model	2000-2006	12
†Puett et al. 2011	Health Prof	full model	1989-2003	17.8 (4.3)
†Hart et al. 2011	TrIPS		1985-2000	14.1 (4)
†Kloog et al. 2013	MA cohort	CVD+Resp	2000-2008	9.9 (1.6)
†Garcia et al. 2015	CA cohort	Kriging	2006	13.06
†Garcia et al. 2015	CA cohort	IDW	2006	12.94
†Garcia et al. 2015	CA cohort	closest monitor	2006	12.68
†Wang et al. 2016	NJ Cohort		2004-2009	11.3
Enstrom 2005	CA Cancer Prev		1973-1982	23.4
Enstrom 2005	CA Cancer Prev		1983-2002	23.4
Enstrom 2005	CA Cancer Prev		1973-2002	23.4



Policy-Relevant Considerations (Chapter 1)

- **Copollutant Confounding**: Across recent studies examining various health effects and both short- and long-term $PM_{2.5}$ exposures, associations remain relatively unchanged in copollutant models

- **Concentration-Response (C-R) Relationship**: Across studies evidence continues to support a linear, no-threshold C-R relationship

- **PM Components and Sources**: Many $PM_{2.5}$ components and sources are associated with many health effects, and the evidence does not indicate that any one source or component is more strongly related with health effects than $PM_{2.5}$ mass

$PM_{2.5}$ Components and Respiratory Effects

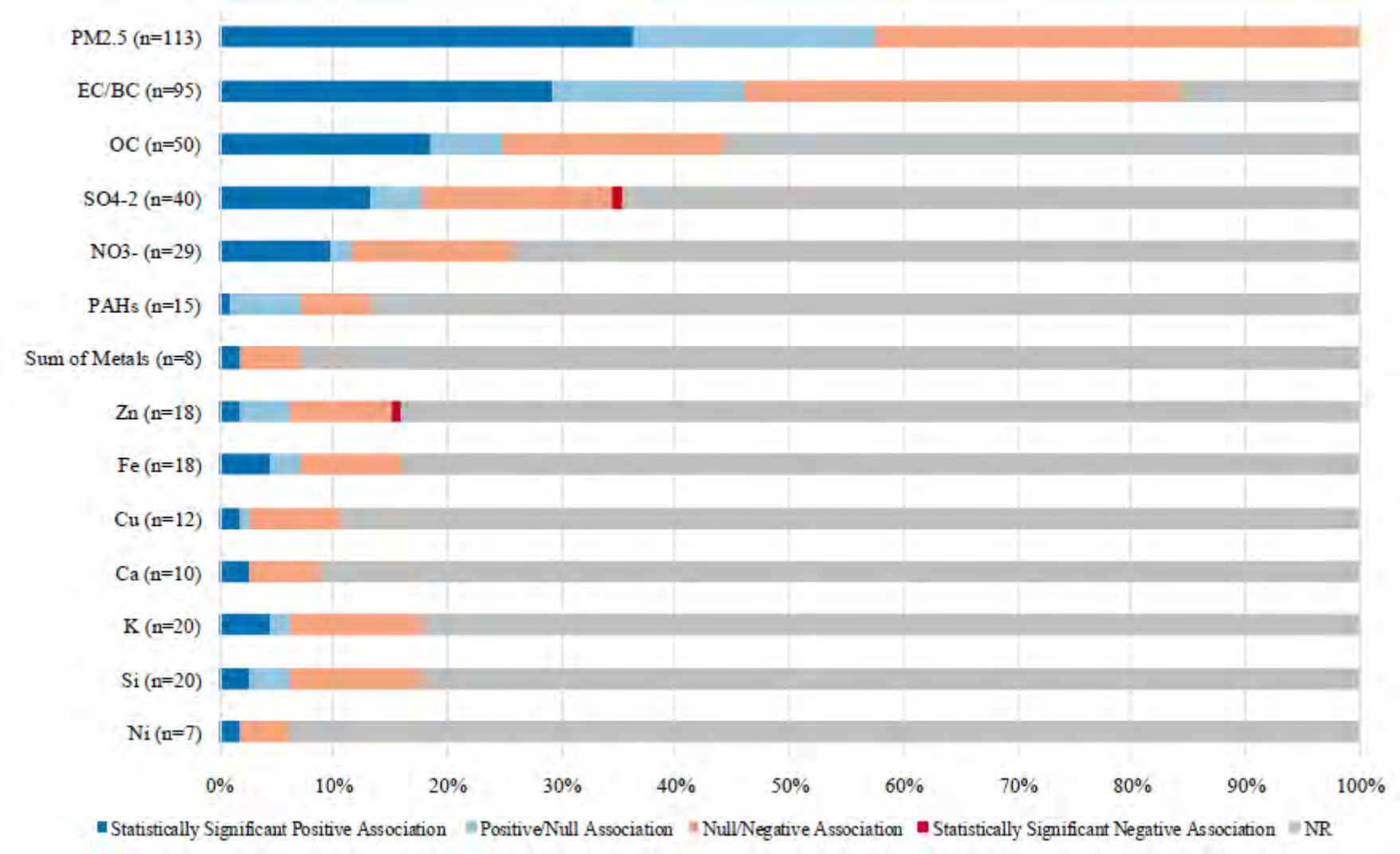


Figure 5-25. Distribution of associations for all respiratory effects and short-term $PM_{2.5}$ mass and $PM_{2.5}$ components exposure.

$PM_{2.5}$ Components and Mortality

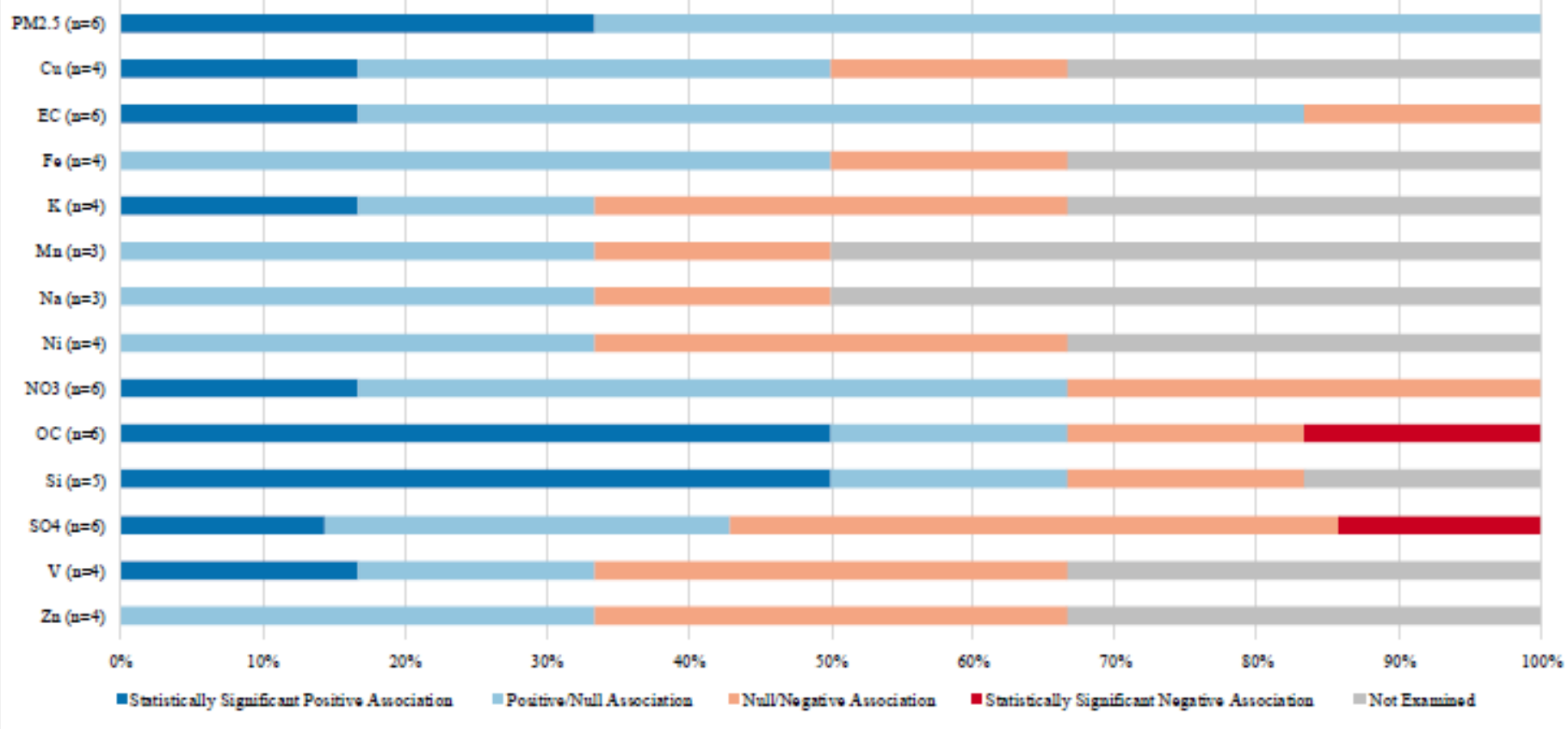
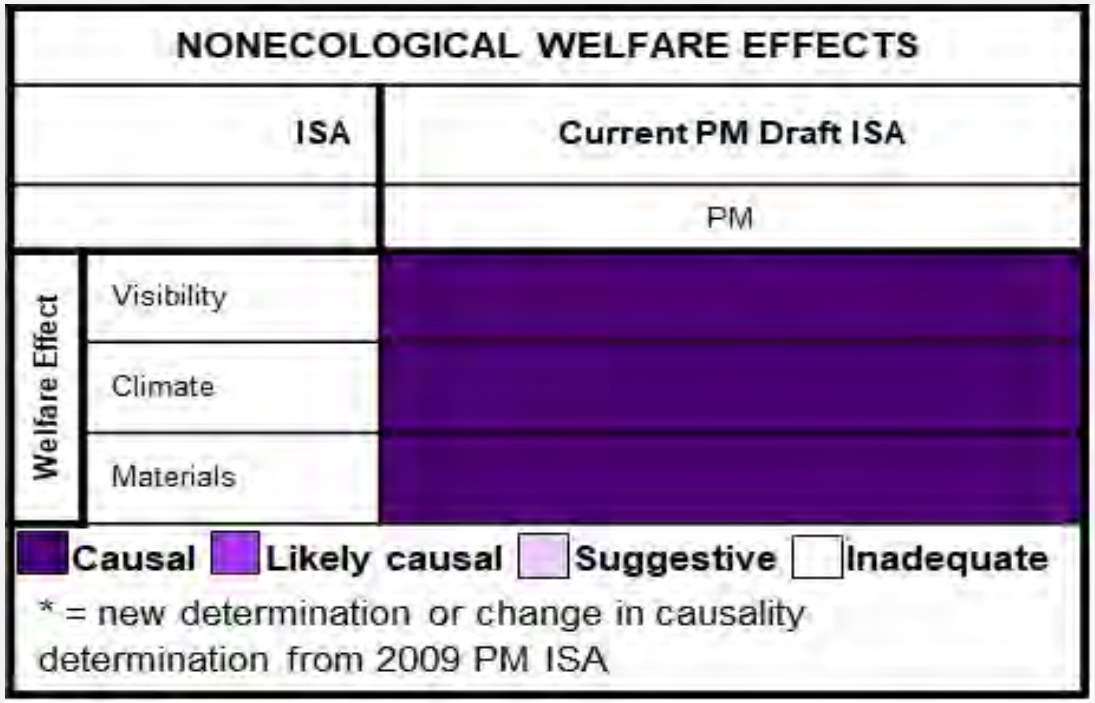


Figure 6-15. Distribution of total (nonaccidental) mortality associations for short-term $PM_{2.5}$ and $PM_{2.5}$ components exposure.

Scope (cont.)

- Welfare Effects
  - Focus is on non-ecological welfare effects
    - Visibility Impairment
    - Climate Effects
    - Materials Effects
  - Ecological effects resulting from the deposition of PM and PM components are being considered as part of the review of the secondary (welfare-based) NAAQS for oxides of nitrogen, oxides of sulfur and PM

Draft PM ISA
Welfare Effects: Causality Determinations



C68

Welfare Effects (Chapter 13)

Recent evidence supports and extends the conclusions of the 2009 PM ISA that there is a causal relationship between PM and welfare effects

- Visibility Impairment **(Causal)**
  - Long-term visibility improvements throughout the U.S as PM concentrations have decreased
  - Regional and seasonal patterns in atmospheric visibility parallel PM concentration patterns
  - More evidence supporting the relationship between visibility and PM composition
- Climate Effects **(Causal)**
  - New evidence provides greater specificity about radiative forcing
  - Increased understanding of additional climate impacts driven by PM radiative effects
  - Improved characterization of key sources of uncertainty particularly with response to PM-cloud interactions
- Materials Effects **(Causal)**
  - New information for glass and metals including modeling of glass soiling
  - Progress in the development of quantitative dose-response relationships and damage functions for materials in addition to stone, including glass and metals
  - Quantitative research on PM impacts on energy yield from photovoltaic systems

At-Risk Framework Description

Classification	Health Effects
Adequate evidence	There is substantial, consistent evidence within a discipline to conclude that a factor results in a population or lifestage being at increased risk of air pollutant-related health effect(s) relative to some reference population or lifestage. Where applicable, this evidence includes coherence across disciplines. Evidence includes multiple high-quality studies.
Suggestive evidence	The collective evidence suggests that a factor results in a population or lifestage being at increased risk of air pollutant-related health effect(s) relative to some reference population or lifestage, but the evidence is limited due to some inconsistency within a discipline or, where applicable, a lack of coherence across disciplines.
Inadequate evidence	The collective evidence is inadequate to determine whether a factor results in a population or lifestage being at increased risk of air pollutant-related health effect(s) relative to some reference population or lifestage. The available studies are of insufficient quantity, quality, consistency, and/or statistical power to permit a conclusion to be drawn.
Evidence of no effect	There is substantial, consistent evidence within a discipline to conclude that a factor does not result in a population or lifestage being at increased risk of air pollutant-related health effect(s) relative to some reference population or lifestage. Where applicable, the evidence includes coherence across disciplines. Evidence includes multiple high-quality studies.

C70

Excerpt from Preamble to ISAs

Particulate Matter:

Spotlight on Health Protection

Bay Area Air Quality Management District

Michael Kleinman, Ph.D.

- UC Irvine Professor of Environmental Toxicology
- Co-Director of the Air Pollution Health Effects Laboratory in the Department of Community and Environmental Medicine
- Adjunct Professor in College of Medicine
- Serves on the Air District Advisory Council
- Ph.D. in Environmental Health Sciences from New York University

C72

PARTICULATE MATTER A COMPLEX MIXTURE THAT AFFECTS HEALTH

Michael T. Kleinman

With the help of David Herman, Rebecca Johnson, Lisa Wingen and a lot of other people

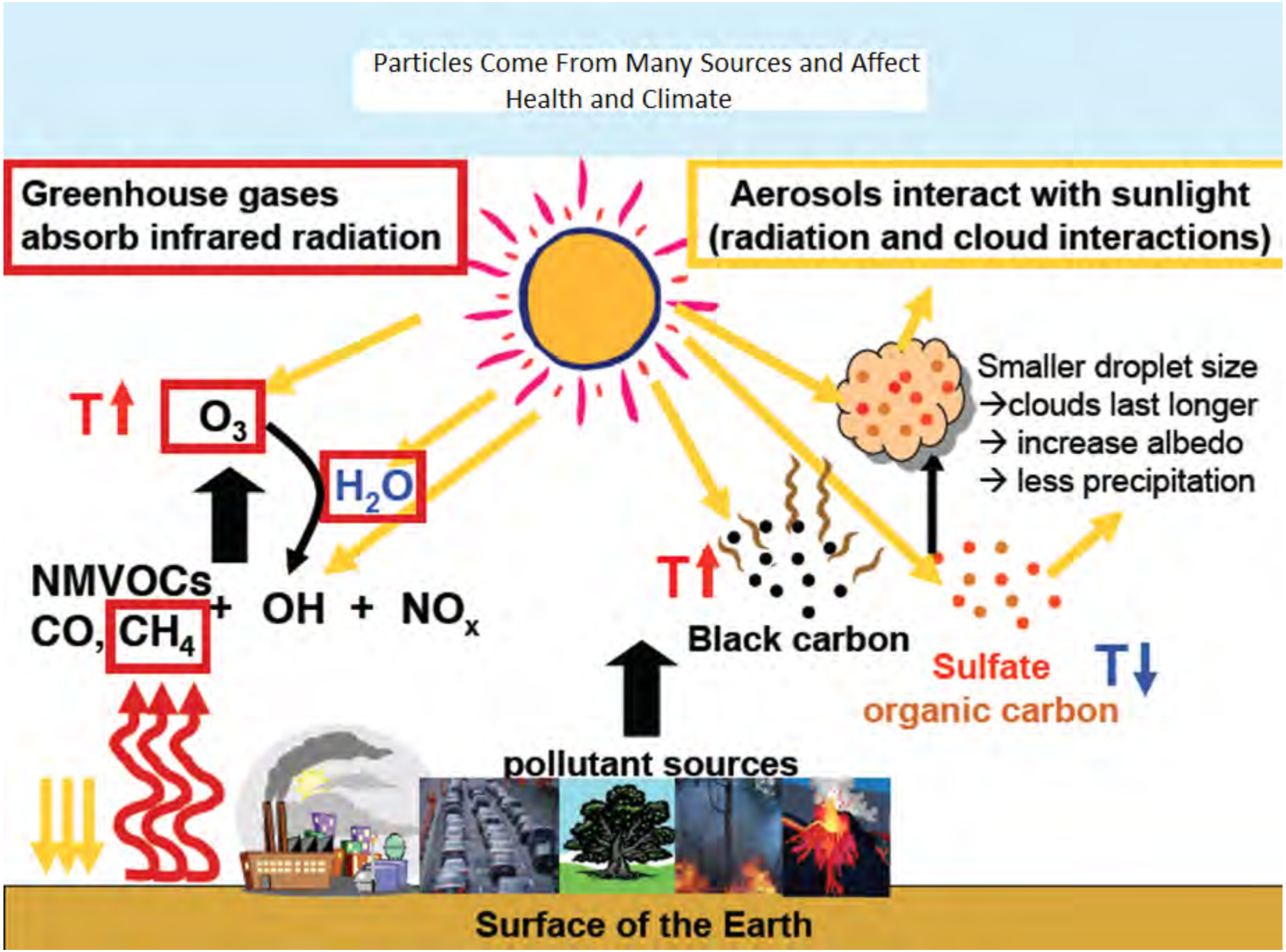
University of California, Irvine

Overall Goal of this Presentation is to Address These Questions

- Why are some species of PM more dangerous than others?
- How does PM affect health?
- Do ultrafine particles (UFPs) have a special role?

What are the health-relevant components of urban air?

- Emissions from power plants, motor vehicles, dust.
- Pollutants gases:
  - Ozone and NO_2 are major problems in California.
  - SO_2 and organic vapors are also important.
- Particles or Particulate Matter (PM):
  - Particles are associated with increased heart-related deaths during air pollution episodes.
  - Toxicology studies show that PM2.5 accelerates the development of atherosclerosis.
  - The strongest associations with human heart-related illness and death are with PM.
  - PM composition includes toxic organic and inorganic chemicals
- Combustion sources generate fine and ultrafine PM often coated with toxic substances.
  - Polycyclic Aromatic Hydrocarbons (PAHs)
  - Carbonyls (acrolein, formaldehyde)
  - Quinones


Particles Come From Many Sources and Affect Health and Climate
Greenhouse gases absorb infrared radiation
Aerosols interact with sunlight (radiation and cloud interactions)
T↑
O_3
H_2O
NMVOCs
CO, CH_4
+ OH + NO_x
Smaller droplet size
→clouds last longer
→ increase albedo
→ less precipitation
T↑
Black carbon
Sulfate
organic carbon
T↓
pollutant sources
Surface of the Earth

Fine (PM2.5) and ultrafine particles (UFP) are the most biologically active

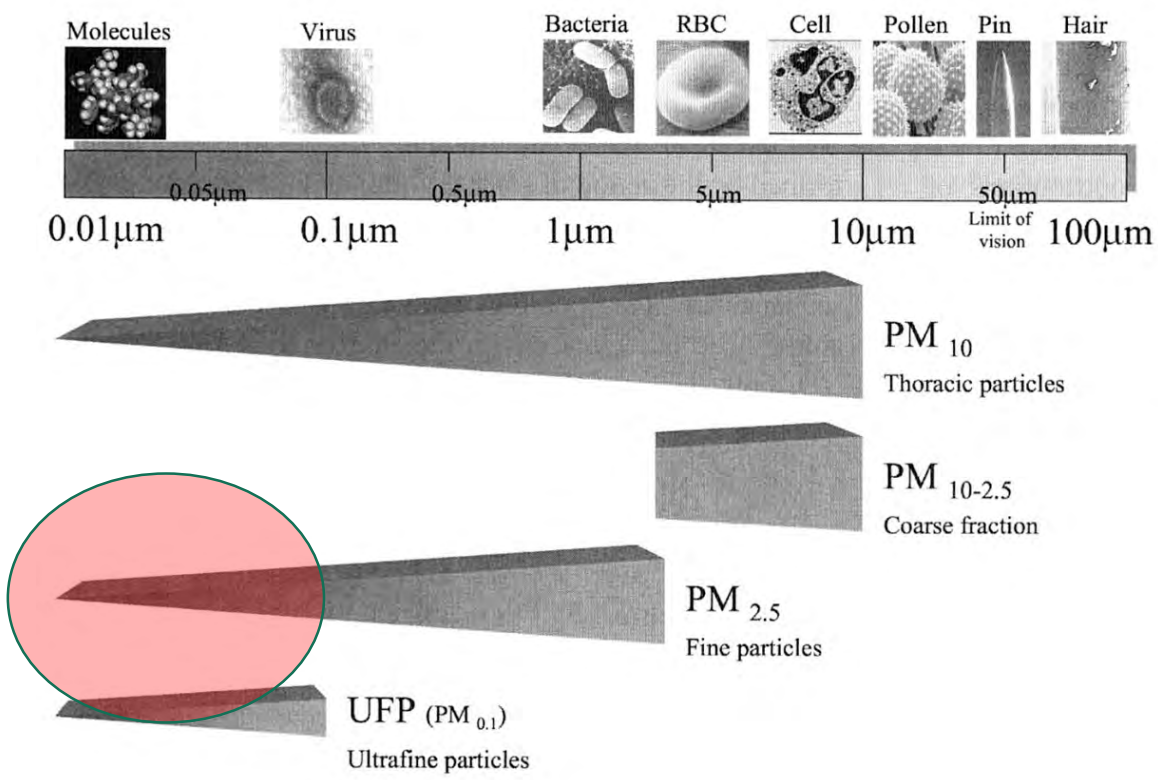


Figure 1. Particulate matter air pollution size distribution.

Combustion Sources Produce Toxic Air Contaminants

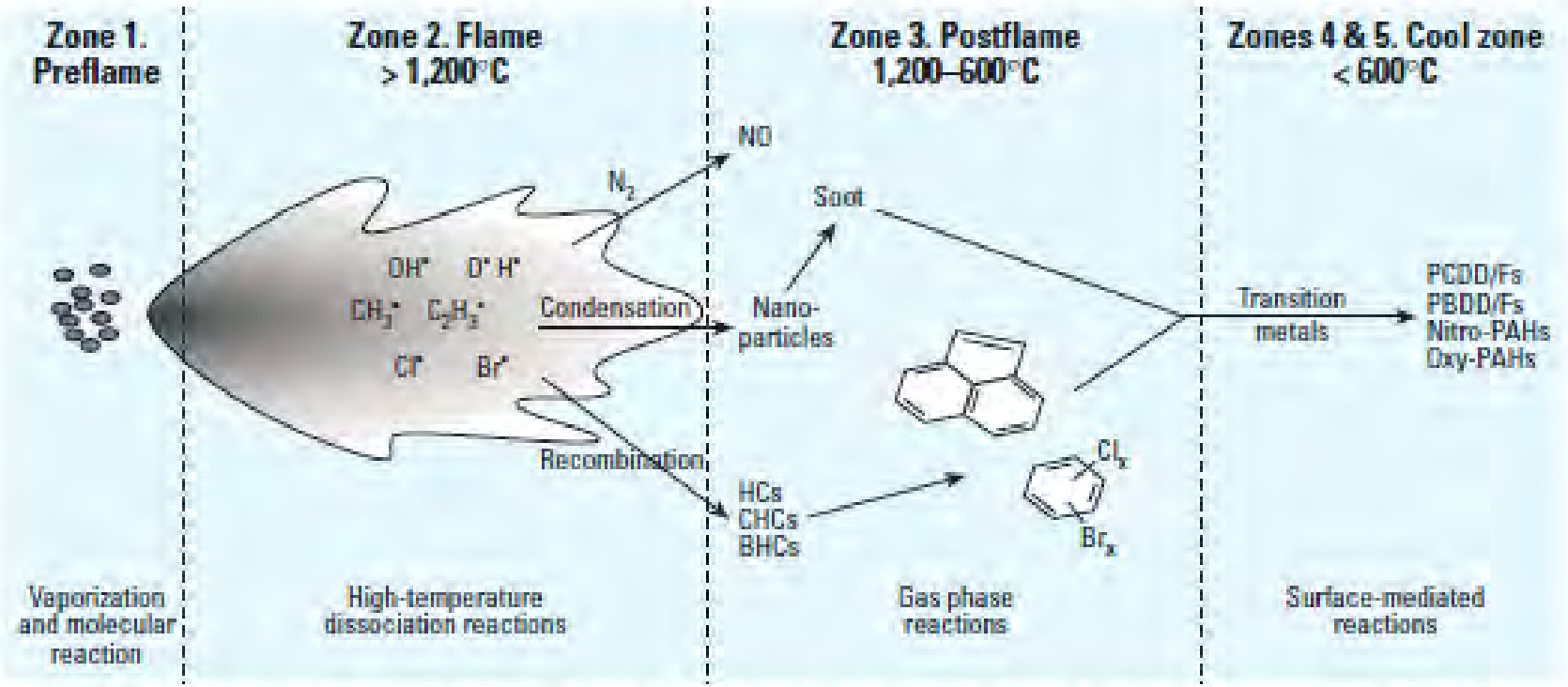


Figure 1. Combustor reaction zones. Zone 1, preflame, fuel zone; zone 2, high-temperature, flame zone; zone 3, postflame, thermal zone; zone 4, gas-quench, cool zone; zone 5, surface-catalysis, cool zone. PBDD/Fs, polybrominated dibenzo-*p*-dioxins and dibenzofurans. Reaction products from upstream zones pass through downstream zones and undergo chemical modifications, resulting in formation of new pollutants. Zone 2 controls formation of many "traditional" pollutants (e.g., carbon monoxide, sulfur oxides, and nitrogen oxides). Zones 3 and 4 control formation of gas-phase organic pollutants. Zone 5 is a major source of PCDD/Fs and is increasingly recognized as a source of other pollutants previously thought to originate in zones 1–4.

Origin and Health Impacts of Emissions of Toxic By-Products and Fine Particles from Combustion and Thermal Treatment of Hazardous Wastes and Materials

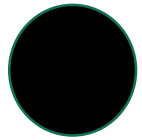
Stephania A. Cormier,[1] Slawo Lomnicki,[2] Wayne Backes,[3] and Barry Dellinger[2]

[1]Department of Biological Science, and [2]Department of Chemistry, Louisiana State University, Baton Rouge, Louisiana, USA; [3]Department of Pharmacology, Louisiana State University Health Sciences Center, Baton Rouge, Louisiana, USA

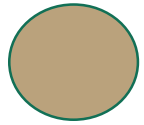
PM2.5 and UFP From Combustion Sources is a Mixture of Solid and Liquid Droplets that we call "SOOT"

- Black carbon (BC) is a major component of "soot", a complex light-absorbing mixture that comprised of a mixture of Elemental Carbon (EC) and Particulate Organic Carbon (OC).
- BC is the most strongly light-absorbing component of particulate matter (PM), and is formed by the incomplete combustion of fossil fuels, biofuels, and biomass.
- BC is emitted directly into the atmosphere in the form of fine particles ($PM_{2.5}$) and ultrafine particles ($PM_{0.1}$). These are also considered nanoparticles.
- BC is the most effective form of PM, by mass, at absorbing solar energy: per unit of mass in the atmosphere, BC can absorb a million times more energy than carbon dioxide (CO_2).
- Organic carbon aerosols are a significant absorber of solar radiation. The absorbing part of organic aerosols is referred to as "brown" carbon (BrC).

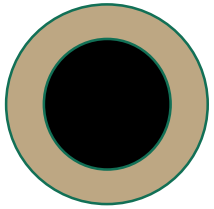
EC



OC + BrC



BC



http://www.epa.gov/blackcarbon/basic.html

1 in 6 deaths, worldwide, is attributable to Pollution

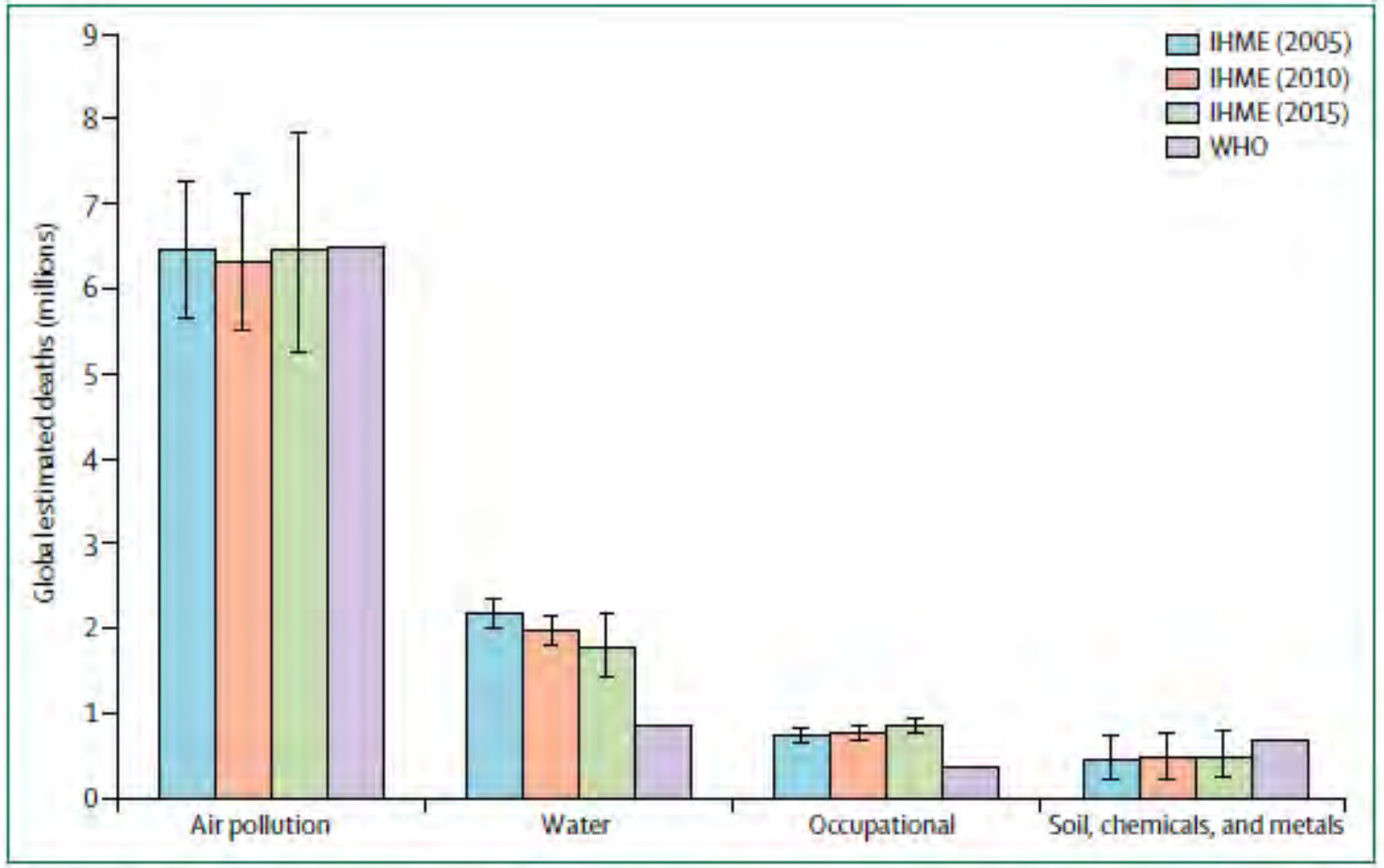


***Figure 4*: Global estimated deaths (millions) by pollution risk factor, 2005–15**
Using data from the GBD study[42] and WHO.[39] IHME=Institute for Health Metrics and Evaluation.

C80