



Particulate Matter: Spotlight on Health Protection

Advisory Council 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

PARTICULATE MATTER REDUCTION STRATEGY REPORT

Statement from the Executive Officer	1
Introduction	3
Particulate Matter Reduction Statements – Table and Council Comments	6
Framework for Evaluating Particulate Matter Reduction Statements – Table and Council Comments	14
Annotated Bibliography for Particulate Matter Reduction Statements and Framework	18
Recommended Actions Table and Council Comments	34

APPENDIX A: ANNOTATED BIBLIOGRAPHY FOR PARTICULATE MATTER REDUCTION STATEMENTS AND FRAMEWORK

Annotated Bibliography - Organized in a Table	A1
---	----

APPENDIX B: SUMMARY OF ADVISORY COUNCIL DELIBERATIONS

July 2020 Deliberations	B1
October 2020 Deliberations	B8
November 2020 Deliberations	PENDING

APPENDIX C: SYMPOSIUM SUMMARIES AND PRESENTATIONS

October 2019

Particulate Matter: Spotlight on Health Protection Report	C1
Panel Presentations	C33

December 2019

Update on Current and Emerging Efforts on Particulate Matter	C238
Panel Presentations	C304

February 2020

Community Particulate Matter Discussion Summary	C393
---	------

May 2020

Community Presentations	C401
<i>Community Reflections from Feb. 27 Community Summit on PM, Jed Holtzman</i>	
<i>COVID While Black, LaDonna Williams</i>	

Air District Presentation: Update on Air District PM Potential Policy Strategies	C421
--	------

July 2020

Industry Presentations	C435
<i>Presentation to BAAQMD Advisory Committee, Frances Keeler</i>	
<i>Assessing the Health Effects of Particulate Matter, Julie E. Goodman</i>	
Air District Presentation: Bay Area PM Modeling-Based Assessments and Next Steps	C464

APPENDIX D: ADVISORY COUNCIL INFORMATION

Advisory Council and Particulate Matter Conference webpage and additional media	D1
Biographies of Advisory Council members	D2

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 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.

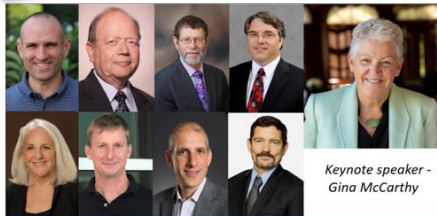
Throughout the past year, in order to further inform Advisory Council deliberations and discussions, Air District staff members and representatives from state-level agencies have also presented to the Advisory Council on particulate matter initiatives, research activities, air quality modeling, and measurement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



Advisory Council Discussion with Experts

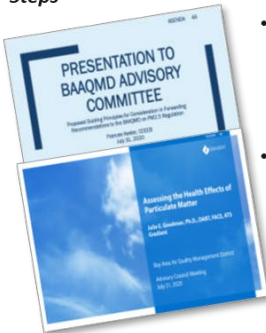
JUNE 29 – JULY 2, 2020

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

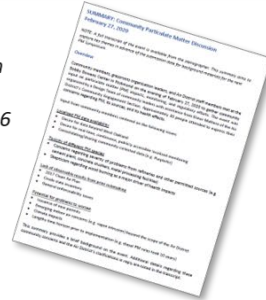
DECEMBER 9, 2019

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

FEBRUARY 27, 2020

Community Particulate Matter Discussion

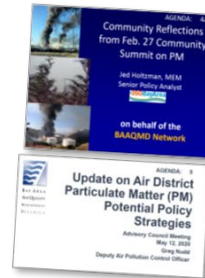
Air District staff met with approx. 30 community members from approx. 16 organizations



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.

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 – TABLE

The Advisory Council has gathered evidence on the current state of particulate matter science and the health impacts and risks of particulate matter exposure. These statements of evidence 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:

<i>ID</i>	<i>PARTICULATE MATTER REDUCTION STATEMENT</i>
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 exposures substantially above standards.
PMRS3	The current particulate matter national ambient air quality standards (NAAQS) are not health protective.
PMRS4	More stringent standards are 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 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.
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.
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.
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, and justifies greater efforts to reduce other sources of PM to reduce overall health risk.
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 lungs but translocate to essentially all organs. Compared to fine particles (PM _{2.5}), they cause more pulmonary inflammation and are retained longer in the lung.

PARTICULATE MATTER REDUCTION STATEMENTS AND
FRAMEWORK – COUNCIL MEMBER COMMENTS**Overarching notes from Councilmembers:**

- Suggest reorder PMRS5→PMRS2; PMRS4→PMRS3; PMRS2→PMRS4, PMRS3→PMRS5; PMRS6→PMRS9; PMRS8→PMRS6; PMRS9→PMRS8
- I think it might be helpful to quote from the e.g. “Based on scientific evidence, as detailed in Attachment B, the 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/m³ to 8 µg/m³. The 24-hour standard should be revised to a range of 30 µg/m³ to 25 µg/m³. These scientific findings are based on consistent epidemiological evidence from multiple multi-city Page 2 of 11 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.”

[https://yosemite.epa.gov/sab/sabproduct.nsf/81DF85B5460CC14F8525849B0043144B/\\$File/Independent+Particulate+Matter+Review+Panel+Letter+on+Draft+PA.pdf](https://yosemite.epa.gov/sab/sabproduct.nsf/81DF85B5460CC14F8525849B0043144B/$File/Independent+Particulate+Matter+Review+Panel+Letter+on+Draft+PA.pdf)

We did not discuss the 24-hour standards - are we focused only on the annual standard?

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.

PREVIOUS: PMRS1) Particulate Matter (PM) is ~~the~~ 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.

Notes on draft:

July 31: Agree

August-September: Reordered

October 9: Agree

Notes from Councilmembers:

- Suggest, “Particulate matter **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.” If it is THE

health driver then it swamps every other health driver and I have a hard time believing that. What about poverty? COVID? Etc.

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 exposures substantially above standards.

*PREVIOUS: PMRS5) 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 exposures substantially above standards. ~~and 3) more stringent standards would be more health protective.~~*

Notes on draft:

July 31: *Revise (refer to Bay Area as a region)*

August-September: *Reordered; Reworded; AD Comments*

October 9: *Statement rewritten to current statement; removed, '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;'* **REVISE**

Notes from Councilmembers:

- *Reorder to make this #2. Suggest replacing with, "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; 3) wildfire smoke increases exposures substantially above standards."*
- *Edited to read (bolded), "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) **meteorological and other weather-related factors cause PM concentrations to vary**; 3) wildfire smoke **events** increases exposures substantially above standards; and 4) **current standards are not sufficiently health protective.**"*

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

*PREVIOUS: **PMRS2)** The current particulate matter national ambient air quality standards (NAAQS) are not **sufficiently** health protective.*

Notes on draft:

July 31: Agree

August-September: Reordered

October 9: Agree; Concern with the term “sufficient”

Notes from Councilmembers:

- Reorder to make this #4. Suggest replacing with, “The current PM national ambient air quality standards (NAAQS) do not prevent adverse health impacts.” Again, what does sufficient mean? What would be sufficient? The wording is problematic.
- Suggest adding “... , **and there is no known safe level of exposure to PM_{2.5}.**”

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

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

Notes on draft:

July 31: Agree

August-September: Reordered

October 9: Edits to the statement made (added ‘and, if met,’); **Agree**

Notes from Councilmembers:

- Reorder to make this #5. Suggest replacing with, “More stringent standards, if met, would save thousands of lives in the U.S. and many in the Bay Area region.”
- Consider adding, “more stringent standards could particularly benefit neighborhoods that have higher exposure levels.”

PMRS5) 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.

*PREVIOUS: **PMRS4)** 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.*

Notes on draft:

July 31: Agree

August-September: Reordered

October 9: Edits to the statement incorporated (removed, 'no evidence of a health effects PM_{2.5} threshold; thus,' and added 'no known safe level of exposure to PM_{2.5}, thus'; **REVISE**

Notes from Councilmembers:

- Reorder to make this #3.
- Delete (with addition of language on no threshold in PMRS2 above)

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/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.

*PREVIOUS: **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/m³ to as low as 8 µg/m³, US EPA's PM_{2.5} NAAQS risk assessment provide scientific evidence that annual average targets in that range ~~national data supports that it~~ would save additional lives.*

Notes on draft:

July 31: Revise to reflect 8 µg/m³ target and evidence from national data

August-September: Amended per note above

October 9: Explain basis for 10 and 8 µg/m³; **REVISE**

Notes from Councilmembers:

- Reorder to make this #6.
- Proposed revision to: "Scientific evidence supports revision of the standard to an annual average in the range of 10 µg/m³ to 8 µg/m³. An Air District target in that range is scientifically supported and would save lives."

- Could we say “The EPA NAAQS risk assessment for PM_{2.5} scientifically supported annual average targets in the range of 8-10 µg/m³”?

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.

PREVIOUS: PMRS7) ~~Allowance should be made for y~~ 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.

Notes on draft:

July 31: n.a.

August-September: Newly added

October 9: REVISE

Notes from Councilmembers:

- Reorder to make this #7. Suggest, “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.”
- Delete; added in PMRS5

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.

PREVIOUS 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.

Notes on draft:

July 31: Agree

August-September: Reordered; Reworded; AD Comments

October 9: Agree

Notes from Councilmembers:

- Reorder to make this #8.

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, and justifies greater efforts to reduce other sources of PM to reduce overall health risk.

*PREVIOUS: **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. Wildfire PM exposure is projected to increase in duration and intensity, due to climate change, and justifies greater efforts to reduce other sources of PM to reduce overall health risk.***

Notes on draft:

July 31: *Not discussed*

August-September: *Reordered; Assume agreement; Not specifically discussed in 7/31 AC Meeting*

October 9: *Added sentence, ‘Wildfire PM exposure is projected to increase in duration and intensity, due to climate change;’ **Agree***

Notes from Councilmembers:

- *Suggest adding, “Wildfire PM exposure is projected to increase in duration and intensity, due to climate change, **and justifies greater efforts to reduce other sources of PM to reduce overall health risk.**” [comment:] I think it’s important to make this point.*

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

Notes on draft:

NEW

Notes from Councilmembers:

- *Moved this statement from recommended actions.*

NEWLY ADDED PMRS11) Ultrafine particles (UFP) which are present in the air in large numbers, pose a health risk. They generally enter the body through the lungs but translocate to essentially all organs. Compared to fine particles (PM_{2.5}), they cause more pulmonary inflammation and are retained longer in the lung.

Notes on draft:

NEWLY ADDED

Notes from Councilmembers:

- Consider adding statement on ultrafine PM since we reference it in a recommendation below on additional monitoring and study of UFPM.

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

Notes on draft:

July 31: Revise (include 8 µg/m³ standard)

August-September: Reordered; Reworded;
AD Comments

October 9: Removed the word 'alternate' after the word 'stringent'; **REVISE**

Notes from Councilmembers:

- Reorder to make this #9.
- Suggest deleting: This seems redundant now
- I propose deleting this because I think it is captured in 5 above

FRAMEWORK FOR EVALUATING PARTICULATE MATTER REDUCTION STRATEGIES – TABLE

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:

<i>ID</i>	<i>FRAMEWORK FOR EVALUATING PARTICULATE MATTER REDUCTION STRATEGIES</i>
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 increased exposure, 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 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, NO _x , NH ₃ , and SO ₂).
F7	PM reduction strategies will need to address multiple source categories.

FRAMEWORK FOR EVALUATING PARTICULATE MATTER REDUCTION STRATEGIES – COUNCIL MEMBER COMMENTS

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

PREVIOUS: F1) ~~Where~~ The Air District should ~~has authority,~~ move as quickly as possible to take maximal feasible action within its authority.

Notes on draft:

July 31: Revise, general agreement

August-September: None

October 9: Agree

Notes from Councilmembers:

- Suggest revision, “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.

Notes on draft:

July 31:

August-September: Newly added

October 9: Re-order #2; Agree

Notes from Councilmembers:

[none as of 10/20/2020]

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.

Notes on draft:

July 31: Agree

August-September: AD Comments

October 9: Re-order needed; Agree

Notes from Councilmembers:

[none as of 10/20/2020]

F4) 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, non-white, low socioeconomic status, elderly).

Notes on draft:

July 31: Agree

August-September: None

October 9: Added, 'U.S. EPA identifies,' Agree

Notes from Councilmembers:

[none as of 10/20/2020]

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

Notes on draft:

July 31: Agree

August-September: None

October 9: Agree

Notes from Councilmembers:

[none as of 10/20/2020]

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, NO_x, NH₃, and SO₂).

Notes on draft:

July 31: Removed reference to "photochemical processes"; Agree

August-September: None

October 9: Agree

Notes from Councilmembers:

[none as of 10/20/2020]

F7) PM reduction strategies will need to address multiple source categories.

Notes on draft:

July 31: Agree

August-September: None

October 9: Agree

Notes from Councilmembers:

[none as of 10/20/2020]

**ANNOTATED BIBLIOGRAPHY FOR PARTICULATE MATTER
REDUCTION STATEMENTS AND FRAMEWORK****PARTICULATE MATTER REDUCTION STATEMENTS**

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.

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 exposures substantially above standards.

References:

- **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.

- **Environmental Protection Agency: Air Quality Designations for the 2012 Primary Annual Fine Particle (PM_{2.5}) National Ambient Air Quality Standards (NAAQS); Final Rule**, available online at <https://www.govinfo.gov/content/pkg/FR-2015-01-15/pdf/2015-00021.pdf>.

This Federal Register document records the U.S. EPA's designations of areas in attainment and nonattainment of NAAQS in 2012, prior to the onset of more frequent wildfires. The San

Francisco Bay Area Air Basin is shown as being in attainment of the 2012 Annual PM_{2.5} NAAQS.

- **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 µg/m³ standard with mortality risk at potential standards of 9 µg/m³, 10 µg/m³, and 11 µg/m³, 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/m³ would save more than 143,000 lives in one decade compared to the current 12µg/m³ 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/m³ NAAQS threshold.

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

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); 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/m³ standard with mortality risk at potential standards of 9 µg/m³, 10 µg/m³, and 11 µg/m³, 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 are 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).**

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/m³ standard with mortality risk at potential standards of 9 µg/m³, 10 µg/m³, and 11 µg/m³, and Table 3-8 calculates the number of lives that could be spared and the potential percent reduction in mortality at these lower PM 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.”

PMRS5) 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.

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 may be warranted; 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.

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).**

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 µg/m³ standard with mortality risk at potential standards of 9 µg/m³, 10 µg/m³, and 11 µg/m³, 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/m³ would save more than 143,000 lives in one decade compared to the current 12µg/m³ 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/m³ NAAQS threshold.

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.

References:

- 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).

- **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.

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.

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.

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, and justifies greater efforts to reduce other 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.

- **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.

NEWLY ADDED PMRS10) 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.

NEWLY ADDED PMRS11) Ultrafine particles (UFP) which are present in the air in large numbers, pose a health risk. They generally enter the body through the lungs but translocate to essentially all organs. Compared to fine particles (PM_{2.5}), they cause more pulmonary inflammation 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.

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

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).

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.

3.3.2.2., Table 3-7 compares mortality associated with PM_{2.5} exposure at the current 12 µg/m³ standard with mortality risk at potential standards of 9 µg/m³, 10 µg/m³, and 11 µg/m³, 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/m³ would save more than 143,000 lives in one decade compared to the current 12µg/m³ 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/m³ NAAQS threshold.

FRAMEWORK

F1) Where the Air District has authority, move quickly to take maximal feasible action.

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) 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 increased exposure, 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 should consider 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 consider emission reduction measures for both primary PM and secondary PM formed in the air (e.g., emissions of precursor ROG, NO_x, NH₃, and SO₂).

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.

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).

RECOMMENDED ACTIONS (TABLE)

The Advisory Council, through feedback from experts, and observation, have identified several actions the Air District can take to reduce particulate matter in the region. These actions include, but are not limited to, the following:

ID	RECOMMENDED ACTIONS
Added RA	Establish a PM _{2.5} target consistent with other findings (e.g. from an annual average of 10 µg/m ³ to as low as 8 µg/m ³).
RA2	Continue working to make air quality data more accessible and timely. Partner with effective formats such as Purple Air.
RA3	Make current PM speciation data more available. Advocate for the U.S. EPA national monitoring guidance and requirements to increase PM speciation.
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.
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.
RA7	Advocate for improved emission estimation and control methods for emerging source categories (e.g., tires & brakes, road dust).
RA8	Develop Air District PM strategic 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.

ID	RECOMMENDED ACTIONS
RA13	Modify permitting regulations to address hyper-localized hotspot health risks.
RA14	Adopt rules incentivizing/requiring building electrification OR ‘Adopt a rule requiring electric appliances rather than gas in new construction.’
RA15	Adopt rule to improve the efficiency of water heaters and space heaters and require electrification of new heaters and other appliances.
RA16	Expand the existing rule to reduce emissions from commercial cooking equipment such as charbroilers (Rule 6-2).
RA17	Update permitting regulations for gas stations and dry cleaners (Regulation 2).
RA18	Adopt amendments to Rule 9-1 to limit sulfur dioxide emissions from refineries.
RA19	Adopt a new rule to limit site-wide health risk from PM.
RA20	Take into account cumulative impact in permitting.
RA21	Close loopholes that allow piecemealing of larger projects into small components.
RA22	Assist local programs to control road dust (e.g., analyze road dust emission rates for local streets).
RA23	Seek federal funding for electrification infrastructure.
RA24	Work to leverage Senate Bill 1 funding to replace switcher engines in East Bay to reduce other off-road sources.
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.
RA26	Seek changes at state level to Air District authority for magnet sources.
RA27	Authorize the Air District to regulate fine PM as toxic air contaminant.
RA28	Seek authority for the Air District to establish air quality standards for PM.
RA29	Support CARB efforts to electrify trucks and other vehicles.
RA30	Seek stricter off-road mobile source rules from CARB.
RA31	Seek authorization from CARB for stronger at-berth regulations to control emissions from ships that dock at ports and refineries.

<i>ID</i>	<i>RECOMMENDED ACTIONS</i>
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.
RA33	Legislative approaches to secure additional authority to regulate PM emissions should be considered, e.g., indirect source rule (ISR) or indoor air quality.
RA34	OEHHA and ARB should be petitioned to identify PM as a toxic air contaminant in light of the available health data.
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.
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.)

RECOMMENDED ACTIONS – COUNCIL MEMBER COMMENTS

Overarching notes from Councilmembers:

- Suggest we consider at least categorizing by priority – e.g. highest priority and all others?

AIR DISTRICT-WIDE

ADDITION RECOMMENDED: Establish a PM_{2.5} target consistent with other findings (e.g. from an annual average of 10 µg/m³ to as low as 8 µg/m³).

Notes on draft:

See note in RA9

Notes from Councilmembers:

- Suggested language, “Establish a PM_{2.5} target consistent with the findings above (e.g., from an annual average of 10 µg/m³ to as low as 8 µg/m³).” Suggested in lieu of RA6
- Suggested language, “**Establish a PM_{2.5} target consistent with the findings above (e.g. from an annual average of 10 µg/m³ to as low as 8 µg/m³.)**” I think this is our key recommendation and should be at or near the front. We did not talk about whether we would prioritize/highlight a few recommendations?

MONITORING

RA2) Continue working to make air quality data more accessible and timely. Partner with effective formats such as Purple Air.

PREVIOUS: RA1) Continue working to make air quality data more accessible and timely. Partner with effective formats such as Purple Air.

Notes on draft:

August-September: AD Comments

October 9: Revised from “closer to real-time” to reflect need for QA/QC

Notes from Councilmembers:

- Suggested addition, “**Partner with effective formats such as Purple Air.**”

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

PREVIOUS: RA2) ~~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.

Notes on draft:

August-September: AD Comments

October 9: Agree

Notes from Councilmembers:

- Delete, “Some species of PM may be more dangerous than others; as yet, no PM species can be exonerated,” Moved to newly added PMRS (between PMRS4 and PMRS5)

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

*PREVIOUS: RA3) Advocate for increased, broader, national monitoring, **exposure,** and **studies of UFP;** ~~support further national studies on the~~ health impacts studies of UFP.*

Notes on draft:

August-September: AD Comments

October 9: Agree

Notes from Councilmembers:

- Suggest, “Advocate for increased, broader, national monitoring, **exposure, and health impacts** studies of UFP.”

TECHNOLOGY

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

*PREVIOUS: RA4) Advocate **for** appropriate federal and state agencies to set improved UFP filtration requirements for on-road vehicles.*

Notes on draft:

August-September: AD Comments

October 9: Council reworded; Agree

Notes from Councilmembers:

- *Seems like this does not belong in technology category.*
- *Add “for”: “Advocate **for** appropriate federal...”*

ENFORCEMENT

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.

PREVIOUS: RA5) 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.

Notes on draft:

August-September: AD Comments

October 9: Council removed, ‘Increase staff for enforcement and accidental release events’; Agree

Notes from Councilmembers:

- *Add “s” after “rule”: “... enforcement of programs and **rules** ...”*

RA6) Increase staff to implement/enforce Rule 11-18.

Notes on draft:

August-September: AD Comments provided and discussed in October meeting.

October 9: Council deleted, Agree

Notes from Councilmembers:

- *I don’t agree with removing without replacing this with something.*

~~**RA7) Devote more staff to risk assessment for air toxics programs like Rule 11-18.**~~

Notes on draft:

August-September: AD Comments provided and discussed in October meeting.

*October 9: Council deleted, **Agree***

Notes from Councilmembers:

- *I don't agree with removing without replacing this with something. Need to replace with something like this, "**Evaluate the effectiveness of Rule 11-18 for reducing PM concentrations from local sources; continue to strengthen implementation and enforcement to ensure efficacy.**"*

ASSESSMENT, INVENTORY, & MODELING DIVISION

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

*PREVIOUS: **RA8)** Advocate for improved emission estimation and control methods for emerging source categories (e.g., tires & brakes, road dust).*

Notes on draft:

August-September:

*October 9: Updated to, "Advocate for improved," added, 'and control,' **Agree***

Notes from Councilmembers:

[none as of 10/20/2020]

PLANNING

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

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

Notes on draft:

August-September: AD Comments

*October 9: Council added, 'strategic' and 'with appropriate targets,'; Add separate recommendation regarding standard; Establish a PM_{2.5} target consistent with the findings above (e.g. from an annual average of 10 µg/m³ to as low as 8 µg/m³); **Agree***

Notes from Councilmembers:

[none as of 10/20/2020]

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.

PREVIOUS RA10) Further develop and implement a strategy of health protective measures and guidance for the community 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.

Notes on draft:

August-September: AD Comments

October 9: Council added, ‘a strategy of’ and ‘and guidance for the community during wildfire episodes;’ **Agree**

Notes from Councilmembers:

- Suggested edit, “Further develop and implement **strategies including** health protective measures and guidance **to protect health** during wildfire episodes.”
[Comment]:

I’m wondering if this document should include any recommendations on things that might be done to reduce PM exposure during wildfire smoke events? E.g.

- *public education*
- *improved real-time monitoring and forecasting models*
- *more comprehensive research to assess short and long-term health impacts and also to assess feasibility of strategies to reduce PM exposure in proposed forest management strategies?*

- establishment of clean air shelters with power, HVAC/HEPA filters, PPE, etc. e.g in schools, community centers, libraries, senior centers, senior living facilities etc. esp in disadvantaged communities
- mobile clean air shelters?
- Strategies to provide HEPA filters for high risk individuals in-home?

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

PREVIOUS: RA11) Develop, fund, implement, and encourage ~~telework~~ strategies to reduce vehicle miles traveled (e.g., active transportation, public transit, ~~telework where possible, and~~ land use planning, and telework).

Notes on draft:

August-September:

October 9: Council reworded and expanded to include additional modes of transit and reducing vehicle miles traveled; **Agree**

Notes from Councilmembers:

- Suggested edit, “**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) Expand community-level exposure and health impact assessments.

Notes on draft:

August-September:

October 9: Removed ‘conduct,’ and changed to ‘expand’; removed ‘health’ and added ‘and health impact’; **Agree**

Notes from Councilmembers:

[none as of 10/20/2020]

RULE DEVELOPMENT

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

PREVIOUS: RA13) Evaluate improvements to existing rules limiting visible emissions and trackout of road dust to address communities that are overburdened.

Notes on draft:

August-September:

October 9: Removed 'expand,' and added, 'Evaluate improvements to;' pluralized 'rule' to 'rules'; added, 'of road dust,' removed reference to rules and removed, 'or experience continuous construction;' Agree

Notes from Councilmembers:

[none as of 10/20/2020]

RA13) Modify permitting regulations to address hyper-localized hotspot health risks.

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

Notes on draft:

August-September: AD provided comment

October 9: Agree

Notes from Councilmembers:

[none as of 10/20/2020]

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

PREVIOUS: RA15) Adopt rules ~~requiring woodburning devices be disabled or replaced when properties are sold.~~ Incentivizing/requiring building electrification OR 'Adopt a rule requiring electric appliances rather than gas in new construction.'

Notes on draft:

August-September:

October 9: Gas replacements; REVISE

Notes from Councilmembers:

- Suggest adding: **“Adopt rules incentivizing/requiring building electrification.”**
[Comment]: What can be done within air district authority to hasten building electrification /replacement of gas stoves, water heaters, heating, etc? Would like to hear from staff re: how to word a recommendation on this.
- Instead of revising this recommendation, I would recommend inserting a new, separate recommendation: **“Adopt a rule requiring electric appliances rather than gas in new constructions.”** I think putting a gas fireplace into a home that already has gas is a huge improvement over a wood-burning fireplace, so I don’t have a problem with gas replacements. I agree, however, that we want to move away from gas in general.

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

PREVIOUS: RA16) Adopt rule to improve the efficiency of water heaters and space heaters and require electrification of new heaters and other appliances.

Notes on draft:

August-September:

October 9: Electrification; REVISE

Notes from Councilmembers:

- Suggest addition (in bold), **“Adopt rule to improve the efficiency of water heaters and space heaters and require electrification of new heaters and other appliances.”**

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

Notes on draft:

August-September: AD provided comment to adjust to, “Expand efforts to reduce emissions from commercial cooking equipment such as charbroilers;” and remove rule reference.

October 9: Not discussed.

Notes from Councilmembers:

- Suggest adding, **“Expand the existing rule to reduce emissions from commercial cooking equipment such as charbroilers with cost-effective measures (Rule 6-2).”**

[Comment]: Perhaps? I'm concerned a bit about struggling restaurants the next few years but otherwise AGREE

- Should this have more specificity?
- Suggest addition (in bold), "Expand the existing rule to reduce emissions from commercial cooking equipment such as charbroilers **and wood-fired ovens** (Rule 6-2)."

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

Notes on draft:

August-September: Air District comment to remove 'and dry cleaners,' with understanding work has been completed.

October 9: Not discussed.

Notes from Councilmembers:

- Suggested revision to read, "... dry cleaners **in order to...**?" [Comment]: How would this impact fine PM?

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

Notes on draft:

August-September: Air District suggests, "Adopt rule amendments to further limit sulfur dioxide emissions from refineries."

October 9: Not discussed.

Notes from Councilmembers:

- Agree

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

Notes on draft:

August-September: Air District suggests, "Adopt a new rule to limit side-wide PM impacts."

October 9: Not discussed.

Notes from Councilmembers:

- Sounds good but how is "site" defined?
- Not sure what this means? Please clarify.

ENGINEERING/PERMITTING

RA20) Take into account cumulative impact in permitting.

Notes on draft:

August-September: None.

October 9: Not discussed.

Notes from Councilmembers:

- *Too vague as written.*
- *Wondering if cumulative risk should also be integrated into the principles/framework above?*

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

Notes on draft:

August-September: Air District suggests, "Evaluate the potential for loopholes that allow piecemealing of larger projects into small components."

October 9: Not discussed.

Notes from Councilmembers:

- *Agree*
- *Unclear if this can be reworded to be more PM specific?*

FUNDING

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

Notes on draft:

August-September: None.

October 9: Not discussed.

Notes from Councilmembers:

- *Agree*

RA23) Seek federal funding for electrification infrastructure.

Notes on draft:

August-September: None.

October 9: Not discussed.

Notes from Councilmembers:

- Agree
- *Is this referring to EV infrastructure? If so, do we need to say anything in the statements above re: EV-PM relationship?*

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

Notes on draft:

August-September: Air District commented that the Air District has previously tried; railroads were not cooperative.

October 9: Not discussed.

Notes from Councilmembers:

- *Need to hear more about this in full context of SB1 funds*

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.

Notes on draft:

August-September: None.

October 9: Not discussed.

Notes from Councilmembers:

- Agree
- *This seems like another of the most important recommendations, especially in light of the increasing proportion of PM from this source.*

AUTHORITY

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

Notes on draft:

August-September: Air District suggests, "Seek tools to enable the Air District to regulate fine PM analogous to a toxic air contaminant."

October 9: Not discussed.

Notes from Councilmembers:

- Too vague as written.

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

Notes on draft:

August-September: None.

October 9: Not discussed.

Notes from Councilmembers:

- Agree, esp. diesel PM

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

Notes on draft:

August-September: Air District suggests, "Advocate for CARB to establish more stringent air quality standards for PM."

October 9: Not discussed.

Notes from Councilmembers:

- Agree
- If staff believe this would improve ability of Air District to make substantial impact, place this a high priority.

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

Notes on draft:

August-September: None.

October 9: Not discussed.

Notes from Councilmembers:

- Agree

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

Notes on draft:

August-September: None.

October 9: Not discussed.

Notes from Councilmembers:

- Agree
- [A comment was here but no content is visible]

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

Notes on draft:

August-September: Air District suggests editing, 'seek authorization from,' to 'Advocate to...'

October 9: Not discussed.

Notes from Councilmembers:

- Agree

ADDITIONAL RECOMMENDED ACTIONS

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.

Notes on draft:

August-September: Suggest adding, 'Air District,' before 'PM action plans,' so reads, 'Air District PM action plans should include...'

October 9: Not discussed.

Notes from Councilmembers:

- Agree
- This seems like it should go in the section above on framework for reduction strategies; these AD recs should be integrated into the other categories e.g. authority, funding, etc.

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

Notes on draft:

August-September: Air District suggests removing.

October 9: Not discussed.

Notes from Councilmembers:

- Agree
- vs. "Draft and pursue legislation to secure additional District authority to regulate PM emissions."

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

Notes on draft:

August-September: Air District suggests removing.

October 9: Not discussed.

Notes from Councilmembers:

- Agree
- vs. "Petition OEHHA and ARB to identify PM as a toxic air contaminant..."

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.

Notes on draft:

August-September: Air District suggests removing.

October 9: Not discussed.

Notes from Councilmembers:

- Agree
- *Is this really about habits? Or is it also about buildings - appliances, leaks, ventilation, etc.? prefer wording such as: "Fund a comprehensive assessment of pathways of indoor PM exposure and strategies to reduce it." With a corollary recommendation re: public education on strategies to reduce indoor PM exposure.*

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.)

Notes on draft:

August-September: Air District suggests removing parenthetical statement.

October 9: Not discussed.

Notes from Councilmembers:

- Agree
- *This also seems like a recommendation that could go into the framework section as a more generic theme, e.g. In developing and implementing strategies and action plans to reduce PM exposures from all sources, Air District will work with county health officials, health care providers, and community-based organizations.*



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 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.	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 exposures 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.	2 a, b, d 3 a, b
PMRS4	More stringent standards are 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 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.	2 b, d
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.	2 a 3 a, b 6 7
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.	4 5 8
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.	9 10
PMRS9	Wildfire PM is a serious contributor to PM health effects; early health studies are of concern; more research on acute and sub-	2 e 11

ID	PARTICULATE MATTER REDUCTION STATEMENT	CITATION #
	chronic effects is ongoing and urgently needed. Wildfire PM exposure is projected to increase in duration and intensity, due to climate change, and justifies greater efforts to reduce other sources of PM to reduce overall health risk.	12
PMRS10	Some species of PM may be more dangerous than others; as yet, no PM species can be exonerated	2f 17 18
PMRS11	Ultrafine particles (UFP) which are present in the air in large numbers, pose a health risk. They generally enter the body through the lungs but translocate to essentially all organs. Compared to fine particles (PM _{2.5}), they cause more pulmonary inflammation 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.	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	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 increased exposure, 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 should consider regional (Bay Area-wide), local (community-level), and localized hot-spot (block-level) sources.	14
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, NO _x , NH ₃ , and SO ₂).	15
F7	PM reduction strategies will need to address multiple source categories.	16 b

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 PM_{2.5} 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/m³ standard with mortality risk at potential standards of 9 µg/m³, 10 µg/m³, and 11 µg/m³, 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](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 Kioumourtoglou, 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/m³ would save more than 143,000 lives in one decade compared to the current 12µg/m³ 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 µg/m³ 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 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 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 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.

- 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.



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 (PM). 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 ($12/35 \mu\text{g}/\text{m}^3$) $PM_{2.5}$ national ambient air quality standards (NAAQS).

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

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 $12 \mu\text{g}/\text{m}^3$ standard at all monitoring locations (**Figure 1**). If targets were set at $10 \mu\text{g}/\text{m}^3$, recent measurements indicate that air quality near the monitoring stations in West Oakland and Laney College would not meet the $10 \mu\text{g}/\text{m}^3$ target. If targets were set at $8 \mu\text{g}/\text{m}^3$, these historical data suggest that nearly all monitoring stations would register Bay Area air quality that would not meet the $8 \mu\text{g}/\text{m}^3$ target.

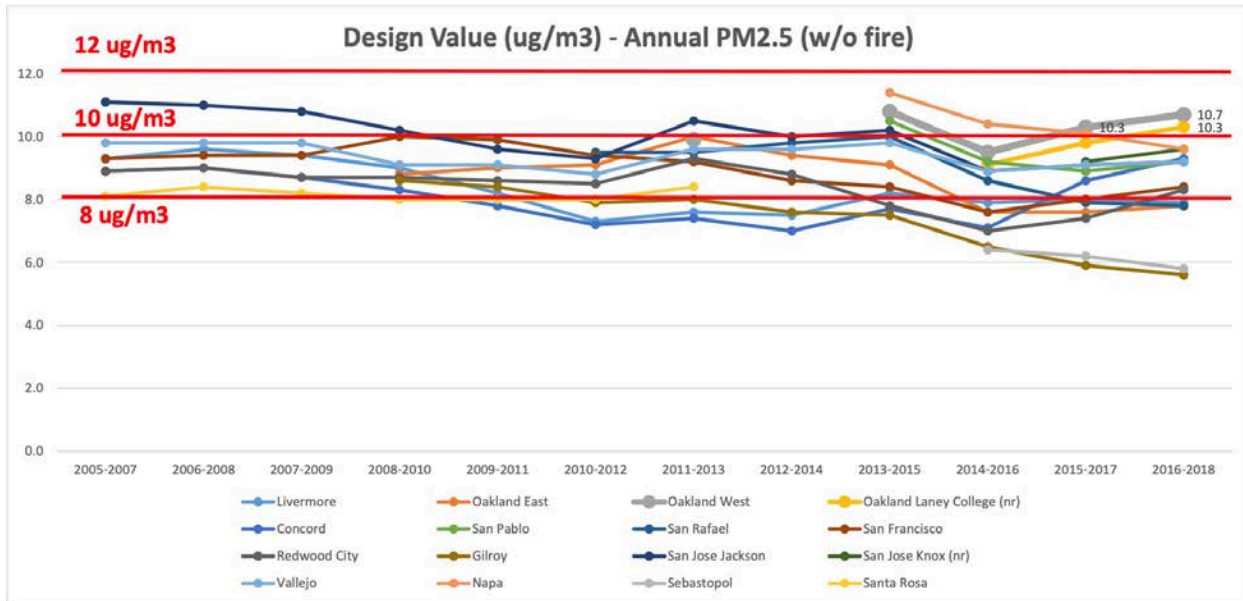


Figure 1 - Estimated annual design values for 16 Air District monitoring stations, 2005-2018

For the 24-hr design values, the Bay Area has been in attainment with the current standard of 35 $\mu\text{g}/\text{m}^3$ for the past decade (Figure 2). If targets were set at the more stringent standard of 25 $\mu\text{g}/\text{m}^3$, 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.

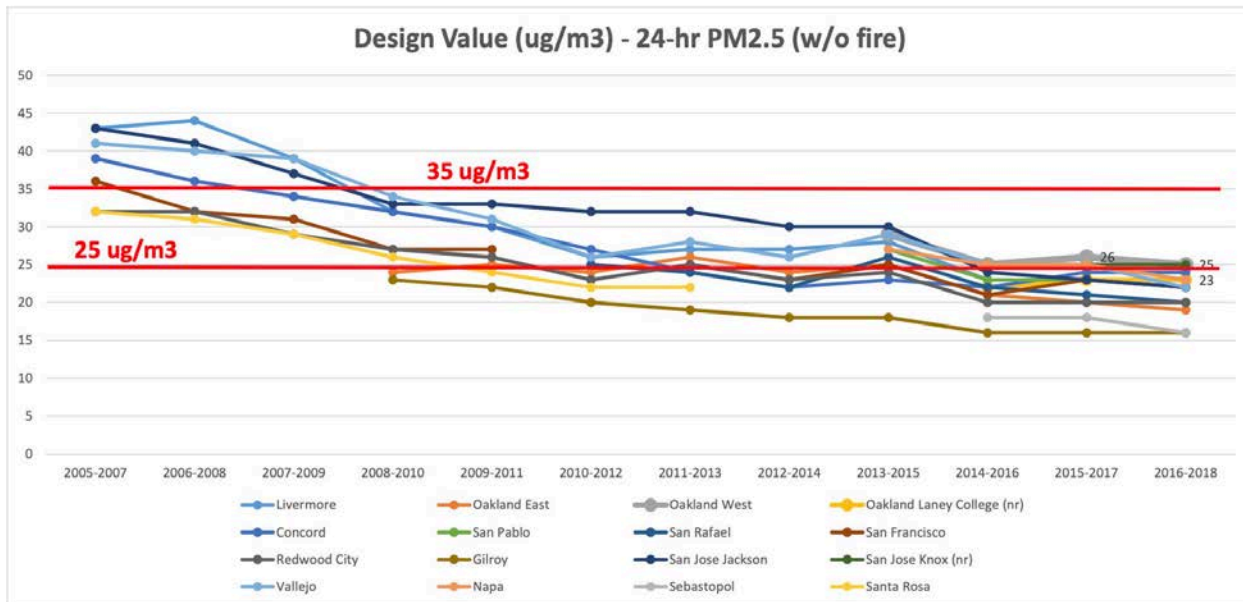


Figure 2 - Estimated 24-hr design values for 16 Air District monitoring stations, 2005-2018

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/m³ and the current federal 24-hr standard of 35 µg/m³.

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/m³ vs 10 µg/m³. Acknowledging that the data and conclusions presented to the 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/m³.

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/m³ or 10 µg/m³) 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/m³) 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/m³ PM_{2.5} NAAQS (except for West Oakland, whose annual average PM_{2.5} in 2018 was above an alternative 10 µg/m³ standard by 0.7 µg/m³, 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/m³.

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/m³.

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/m³ 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, NO_x, NH₃, and SO₂).

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, NO_x, NH₃, and SO₂).*

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 OCTOBER 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 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 µg/m³ to as low as 8 µg/m³.

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 µg/m³ for the region, wildfires resulting in 30 days of exposure to 150 µg/m³ would bring the annual average up to 20 µg/m³, well beyond even the federal standard of 12 µg/m³. 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/m³ to as low as 8 µg/m³, 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 “hotspot” 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 (NO_x), 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.



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	2
Background	6
Morning Panel: PM Health Effects	8
Current State of Particulate Matter Science: Particulate Matter Integrated Science Assessment (PM ISA) (Working Draft Conclusions) (Jason Sacks, MPH, U.S. Environmental Protection Agency).....	8
Particulate Matter: A Complex Mixture that Affects Health (Prof. Michael Kleinman, University of California at Irvine)	10
Particulate Matter Health Effects: What Do We Know and What Do We Still Need to Know? (Dr. John Balmes, University of California at San Francisco & Berkeley)	12
Recent Developments in the Scientific Review of the National Ambient Air Quality Standards for Particulate Matter (Prof. Christopher Frey, North Carolina State University)	14
PM Health Effects: Discussion Summary	16
Afternoon Panel: PM Exposure and Risk	17
Exposure and Risk Panel Particulate Matter: Spotlight on Health (Dr. Lauren Zeise, Cal/EPA, Office of Environmental Health Hazard Assessment).....	17
Location- and source-specific strategies: Consider impact, marginal impact, and environmental justice (Prof. Julian Marshall, University of Washington)	19
Review of the National Ambient Air Quality Standards for Particulate Matter: Overview of the Draft Policy Assessment (Dr. Scott Jenkins, U.S. Environmental Protection Agency)	21
Targeting Particulate Matter: West Oakland Community Emissions Reduction Program (Dr. Phil Martien, Bay Area Air Quality Management District).....	24
PM Exposure and Risks: Discussion Summary	26
Public Comment	27
Advisory Council Deliberation	29
Next Steps	31

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 ($\mu\text{g}/\text{m}^3$) to 8 $\mu\text{g}/\text{m}^3$ (versus the current 12 $\mu\text{g}/\text{m}^3$ standard).
- The 24-hour standard should be lowered to 30 $\mu\text{g}/\text{m}^3$ to 25 $\mu\text{g}/\text{m}^3$ (versus current 35 $\mu\text{g}/\text{m}^3$ standard).
- These changes would save thousands of lives.
- The PM₁₀ 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.

PM Exposures and Risks

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 µg/m³ 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.

Public comment

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 disproportionately 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

<i>Main takeaway</i>	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.

<i>Main takeaways</i>	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

<i>Main takeaways</i>	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

<i>Main takeaways</i>	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/m³ to 8 µg/m³ (versus the current 12 µg/m³ standard)
- The 24-hour standard should be lowered to 30 µg/m³ to 25 µg/m³ (versus the current 35 µg/m³ standard)
- These changes would save thousands of lives
- The PM₁₀ 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/m³ 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 $8 \mu\text{g}/\text{m}^3$, the lack of data on lower levels of exposure makes it appropriate to recommend $8 \mu\text{g}/\text{m}^3$ for a present limit. In response to a question from Council Member Solomon, Professor Frey clarified that this $8 \mu\text{g}/\text{m}^3$ 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 $\text{PM}_{2.5}$ and efforts to control $\text{PM}_{2.5}$ 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

<i>Main takeaways</i>	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 µg/m³ and one-hour averages above 300 µg/m³ in some areas. In West Oakland, wildfire

impacts on PM have driven annual averages above the national standard, to 12.9 $\mu\text{g}/\text{m}^3$ in 2017 and 14.4 $\mu\text{g}/\text{m}^3$ 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

<i>Main takeaways</i>	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

<i>Main takeaways</i>	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 $12 \mu\text{g}/\text{m}^3$ standard in comparison to “just meeting” 11, 10, and $9 \mu\text{g}/\text{m}^3$. 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 $\text{PM}_{2.5}$ 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 $\text{PM}_{2.5}$ -associated deaths per year at concentrations above $10 \mu\text{g}/\text{m}^3$. 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 $\text{PM}_{2.5}$ -associated deaths. The panelist responded that the estimates of $\text{PM}_{2.5}$ -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 $1 \mu\text{g}/\text{m}^3$ 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

<i>Main takeaways</i>	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 µg/m³ 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

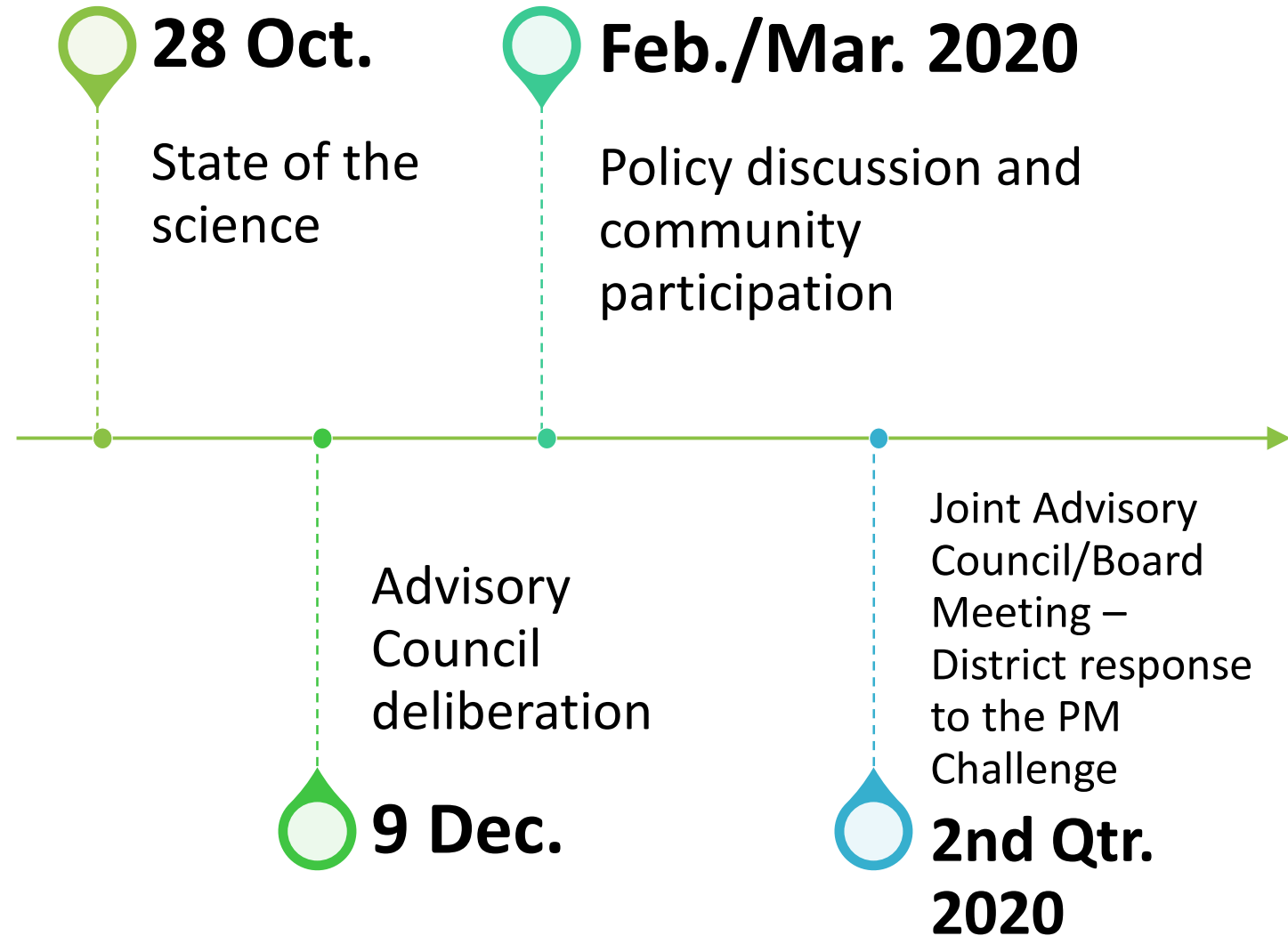
Introduction

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

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.

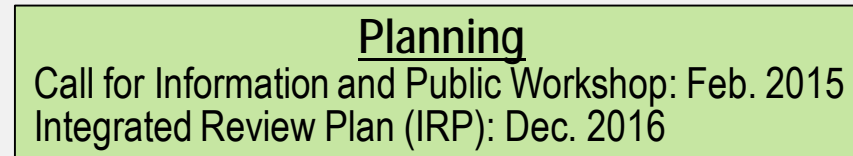
Outline

- 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

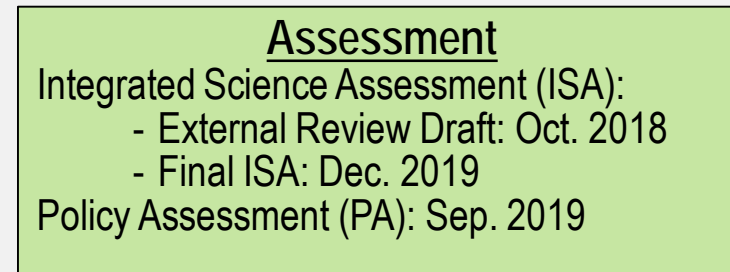
Overview of the Process for Reviewing the PM NAAQS

- **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

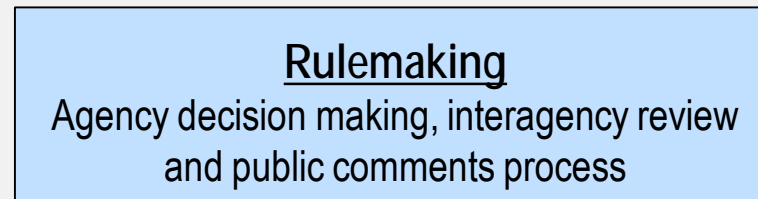
2014-2016



2018-2020



2020



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/m³; 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			
		Pregnancy and Birth Outcomes			
	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

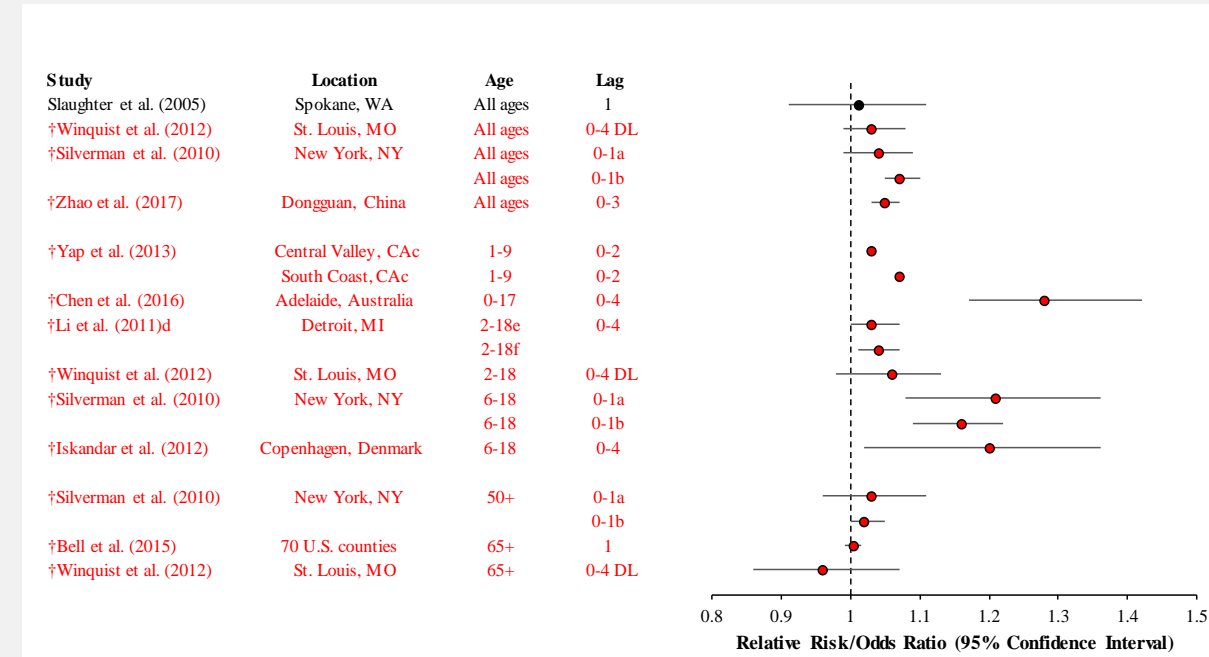


Figure 5-2. Summary of associations between short-term PM_{2.5} exposures and asthma hospital admissions for a 10 µg/m³ increase in 24-hour average PM_{2.5} concentrations.

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

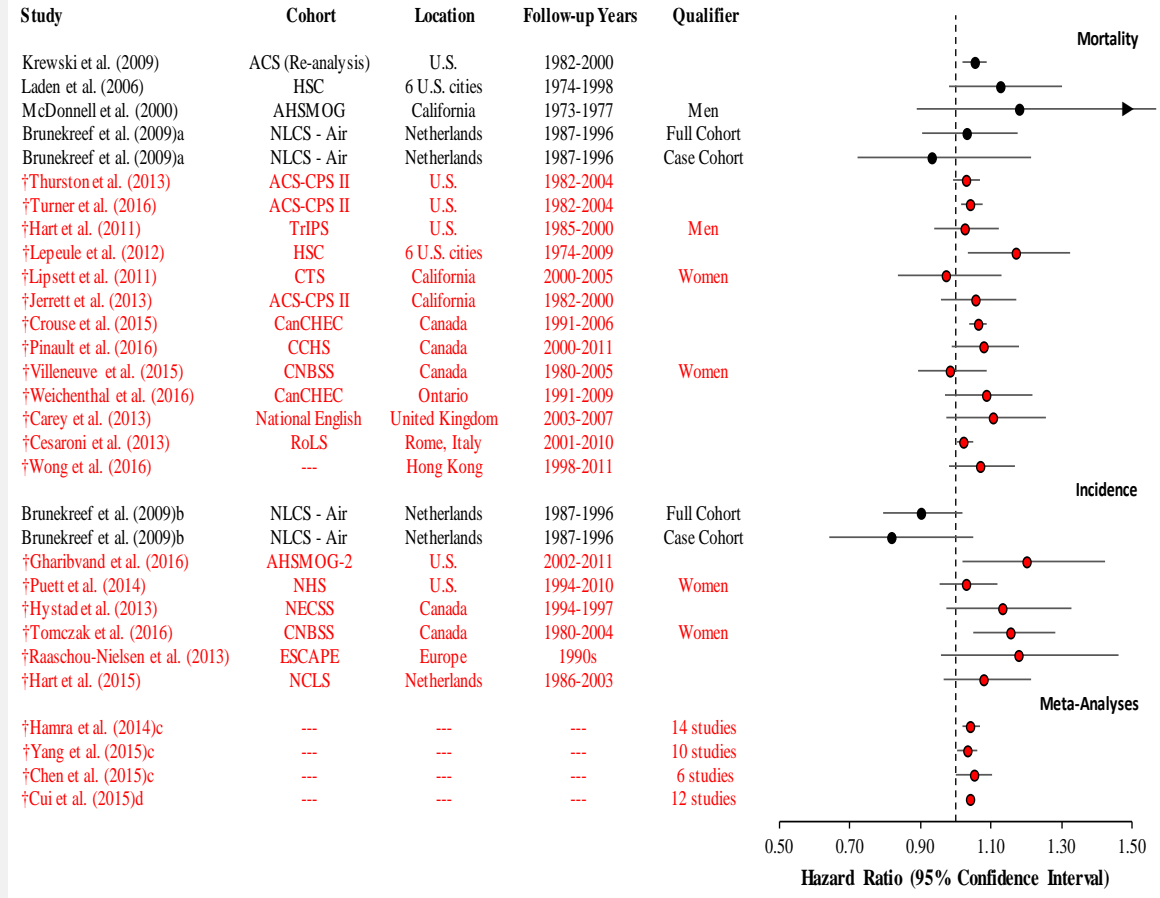
Nervous System Effects

- 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

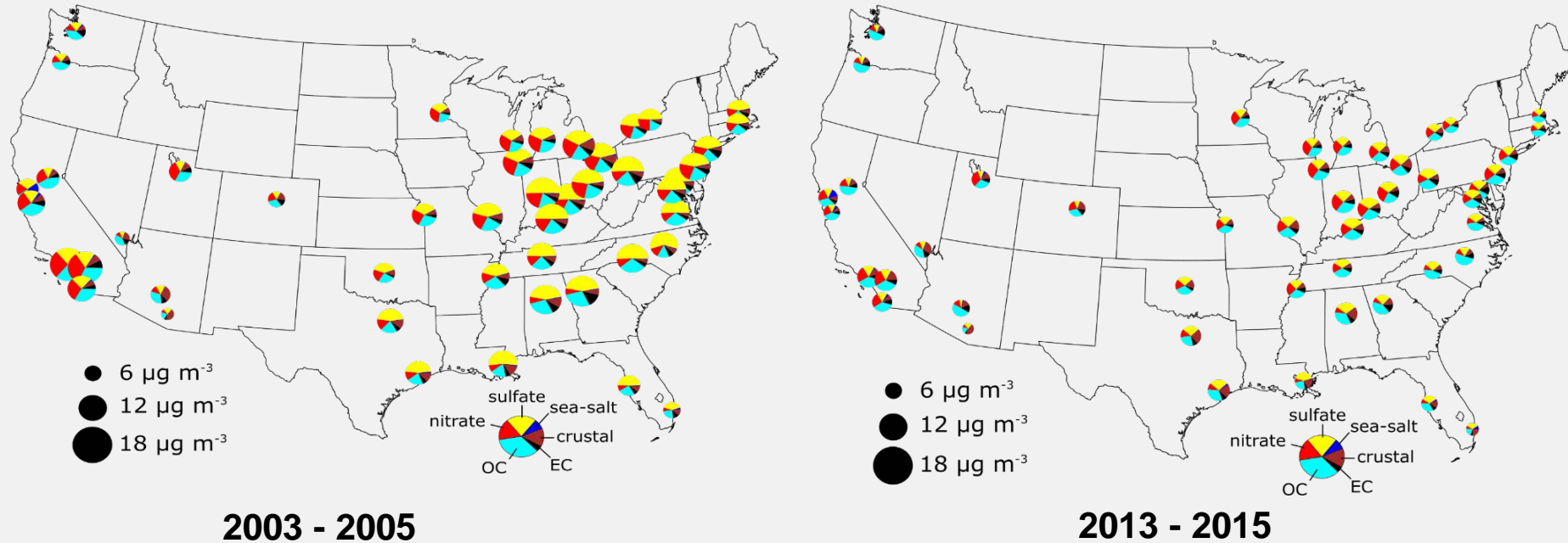
Figure 10-3. Summary of associations reported in previous and recent cohort studies that examined long-term PM_{2.5} exposure and lung cancer mortality and incidence.

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: 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

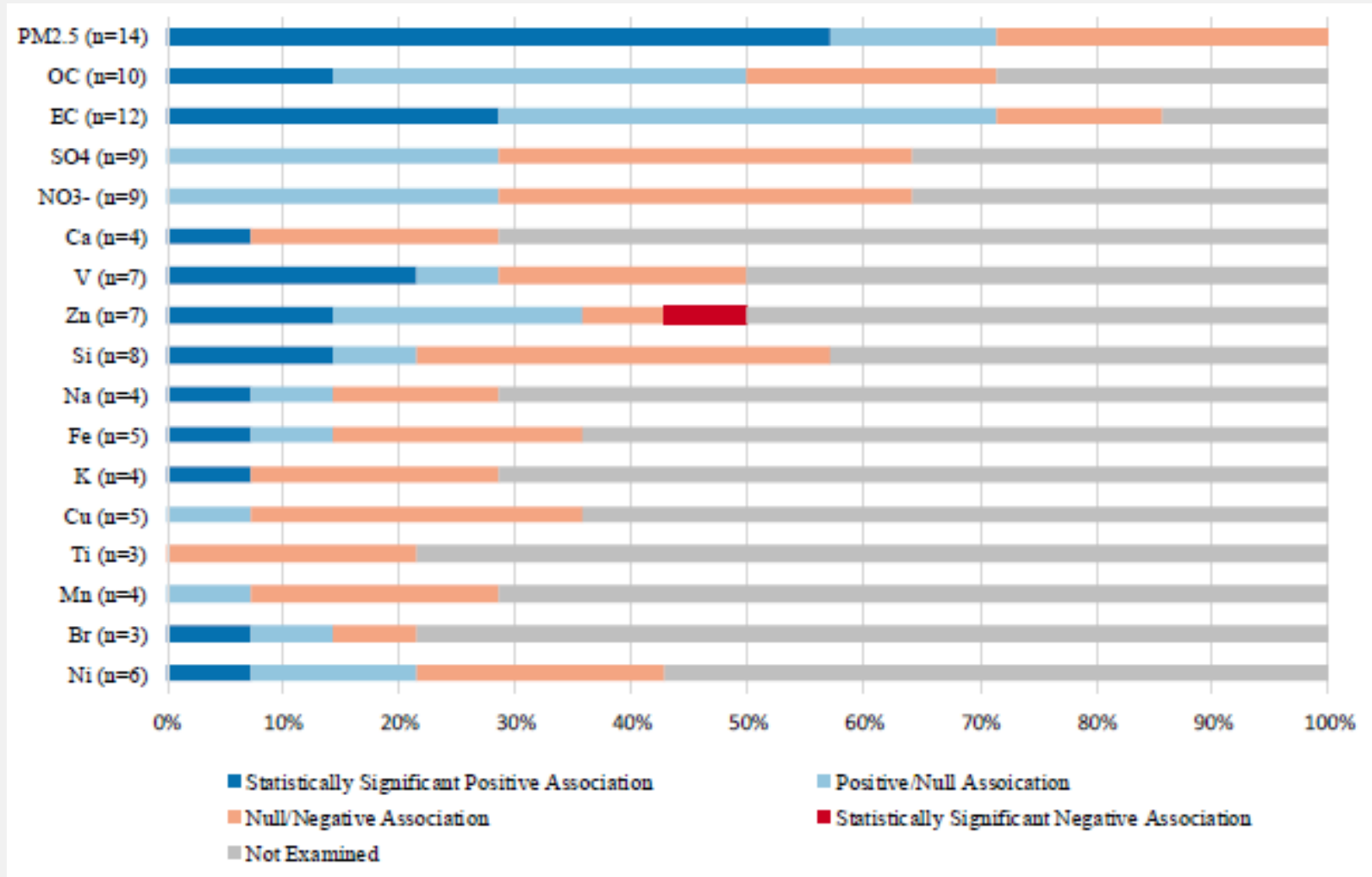


Figure 6-15. Distribution of associations for hospital admissions and emergency department visits for cardiovascular-related effects and short-term PM_{2.5} and PM_{2.5} components exposure.

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

PM ISA Team

NCEA Team

Jason Sacks (Assessment Lead)
 Barbara Buckley (Deputy Lead)
 Michelle Angrish
 Renee Beardslee**†
 Adam Benson*†
 James Brown
 Evan Coffman
 Elizabeth Chan**
 Allen Davis
 Steve Dutton
 Brooke Hemming
 Erin Hines
 Ellen Kirrane
 Dennis Kotchmar
 Meredith Lassiter
 Vijay Limaye###†
 Tom Long
 Tom Luben
 April Maxwell*†
 Joseph McDonald***

Steve McDow
 Ihab Mikati*†
 Jennifer Nichols
 Molini Patel†
 Rob Pinder+
 Joseph Pinto**
 Kristen Rappazzo
 Jennifer Richmond-
 Bryant
 Lindsay Stanek#
 Michael Stewart
 Chris Weaver

* ORISE
 ** Postdoctoral Fellow
 *** NRMRL/OTAQ
 # NERL
 ## Region 5
 + OAQPS
 ++ Retired
 † Separated

Health & Environmental Effects Assessment Division

John Vandenberg, Director
 Steve Dutton, Associate Director
 Jane Ellen Simmons, Branch Chief
NCEA Management (Retired/Previously Acting)
 Debra Walsh, Deputy Director (Retired)
 Reeder Sams, Deputy Directory (Acting)
 Andrew Hotchkiss, Branch Chief (Acting)
 Alan Vette, Branch Chief (Acting)
 Jennifer Richmond-Bryant, Branch Chief (Acting)
 Tara Greaver, Branch Chief (Acting)
 Jennifer Nichols, Branch Chief (Acting)

Technical Support

Marieka Boyd
 Ryan Jones
 Connie Meacham**
 Shane Thacker

External Authors

Neil Alexis
 Matt Campen
 Sorina Eftim
 Allison Elder
 Jay Gandy
 Katie Holliday
 Veli Matti Kerminen
 Igor Koturbash
 Markku Kulmala
 Petter Ljungman
 William Malm
 Loretta Mickley
 Marianthi-Anna Kioumourtzoglou
 James Mulholland
 Maria Rosa
 Armistead Russell
 Brett Schichtel
 Michelle Turner
 Laura Van Winkle
 James Wagner
 Greg Wellenius
 Eric Whitsel
 Catherine Yeckel
 Antonella Zanobetti
 Max Zhang

Supplemental Materials

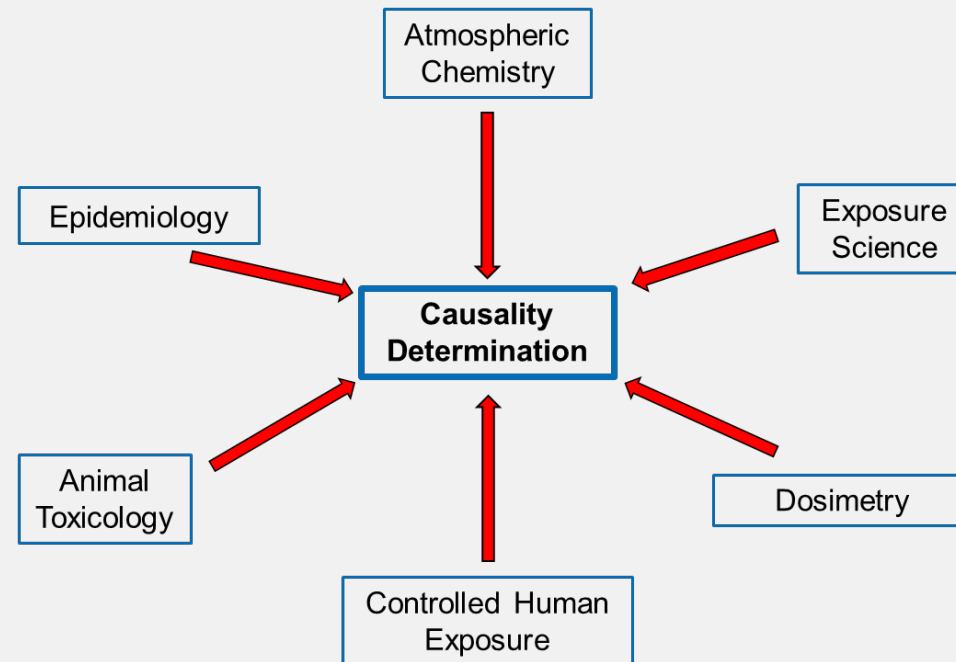
Framework for Causality Determinations in the ISA

	Health Effects	Ecological and Other Welfare Effects
Causal relationship	<p>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 have been shown to result in health effects and other biases could be ruled out with reasonable confidence. (1) controlled human exposure studies that demonstrate consistent effects, or (2) observational studies that cannot be explained by chance, confounding, and other biases with reasonable confidence (e.g., animal studies or mode of action information). Generally, the determination is based on multiple high-quality studies conducted by multiple research groups.</p>	<p>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 relationship is usually obtained from the joint consideration of many lines of evidence that reinforce each other.</p>
Likely to be a causal relationship	<p>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 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.</p>	<p>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 and other lines of evidence are limited or inconsistent. Generally, the determination is based on multiple studies by multiple research groups.</p>
Suggestive of, but not sufficient to infer, a causal relationship	<p>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 shows an association with 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.</p>	<p>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.</p>
Inadequate to infer a causal relationship	<p>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.</p>	<p>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.</p>
Not likely to be a causal relationship	<p>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 lifestyles, are mutually consistent in failing to show an effect at any level of exposure.</p>	<p>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.</p>

Evaluation of the Scientific Evidence

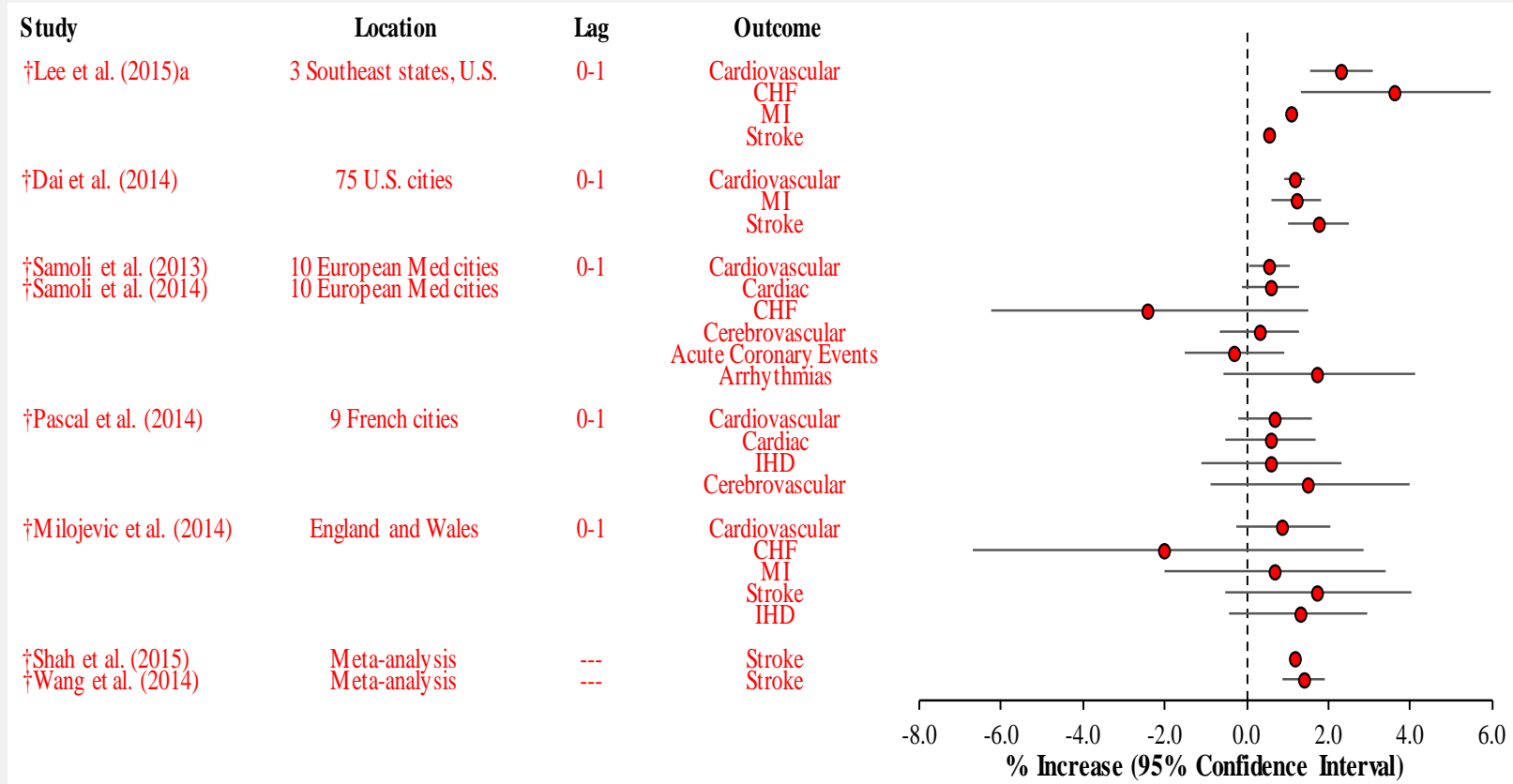
- Organize relevant literature for broad outcome categories
- Evaluate studies, characterize results, extract relevant data
- Integrate evidence across disciplines for outcome categories
- Develop causality determinations using established framework
- Evaluate evidence for populations potentially at 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



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

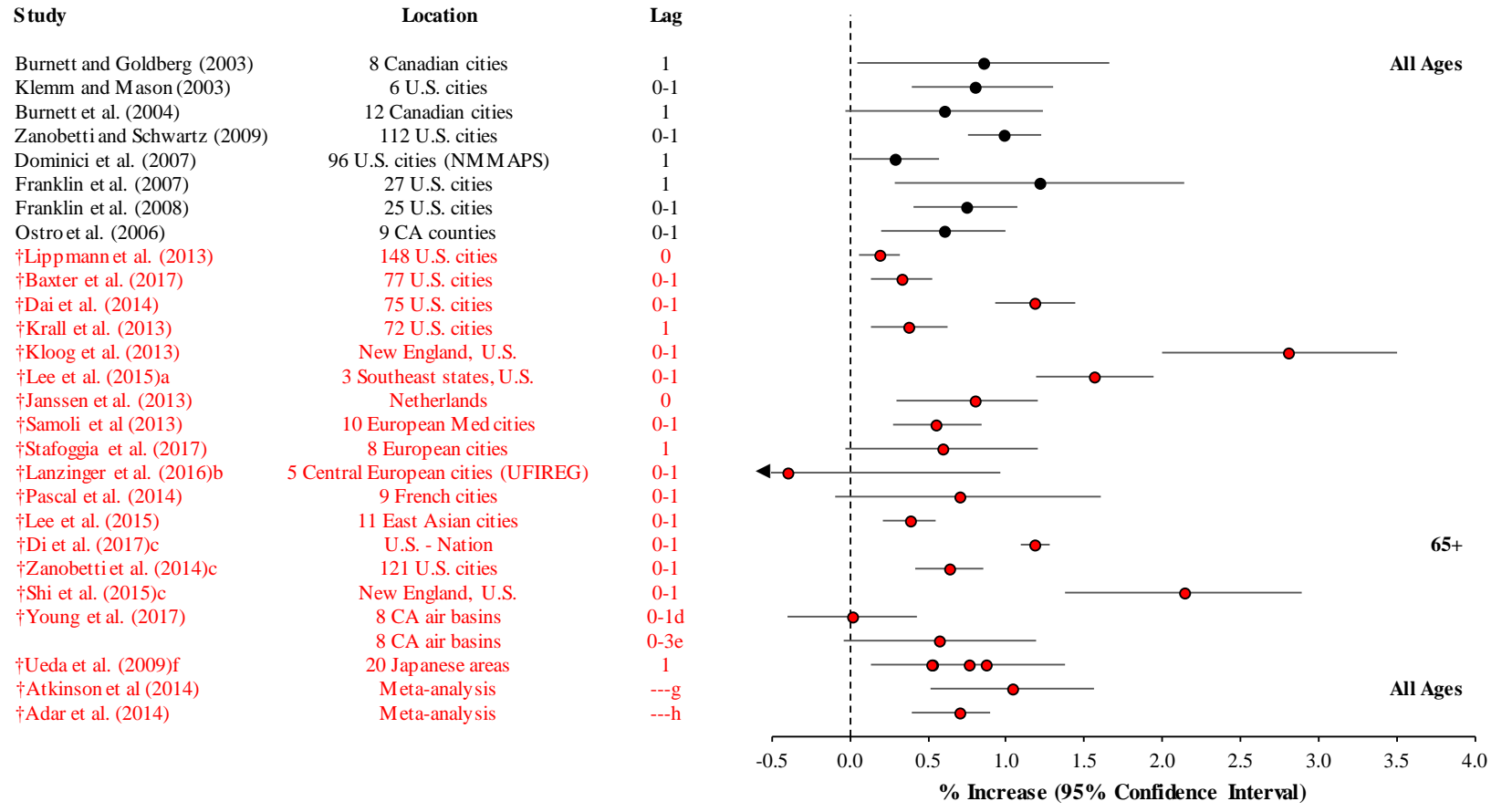


Note: Red = recent studies; Black = studies evaluated in the 2009 PM ISA

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.

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.

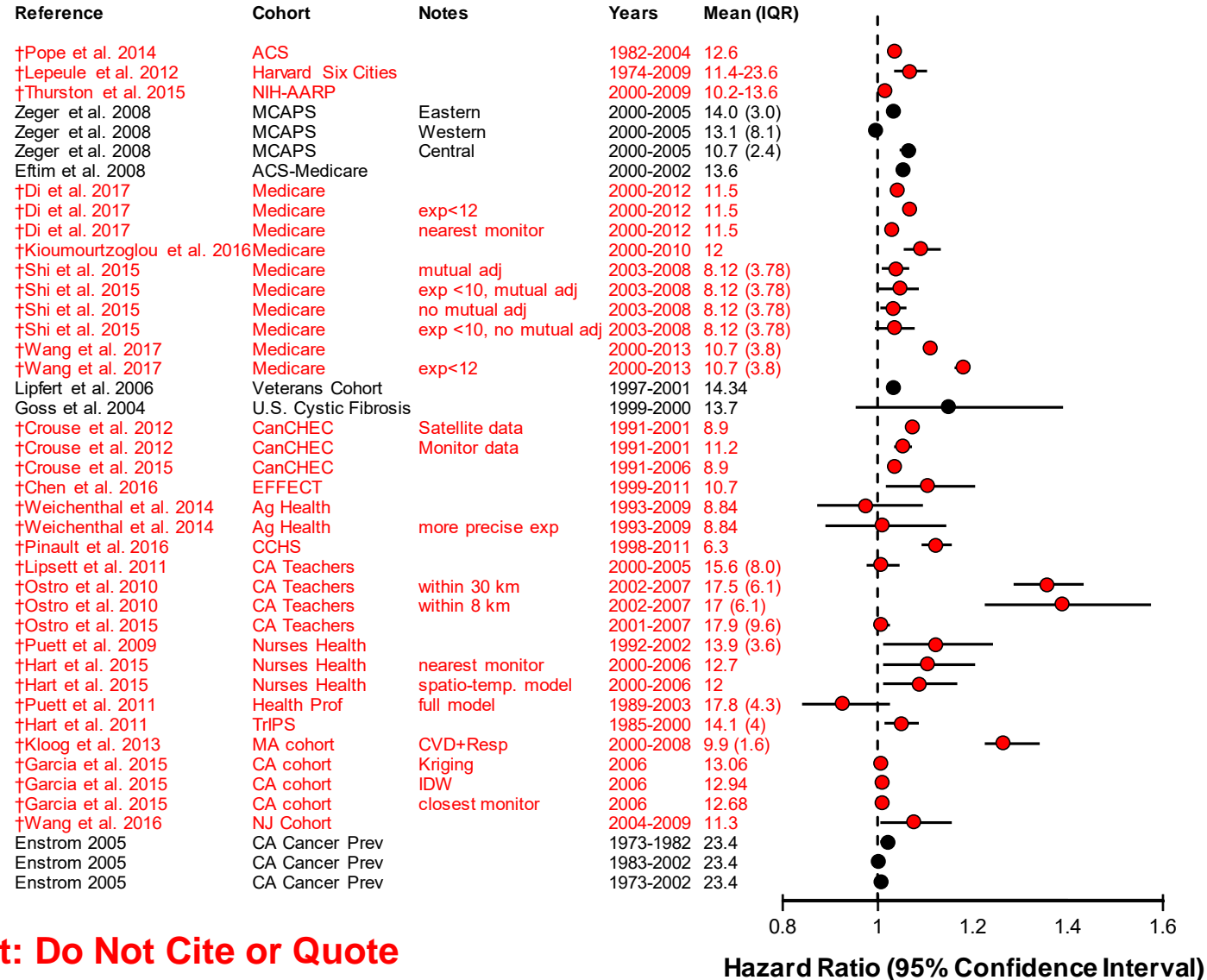
Mortality – Long-term PM_{2.5} Exposure

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/m³ increase in pollutant concentration.

Red = recent studies;
Black = studies evaluated in the 2009 PM ISA



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

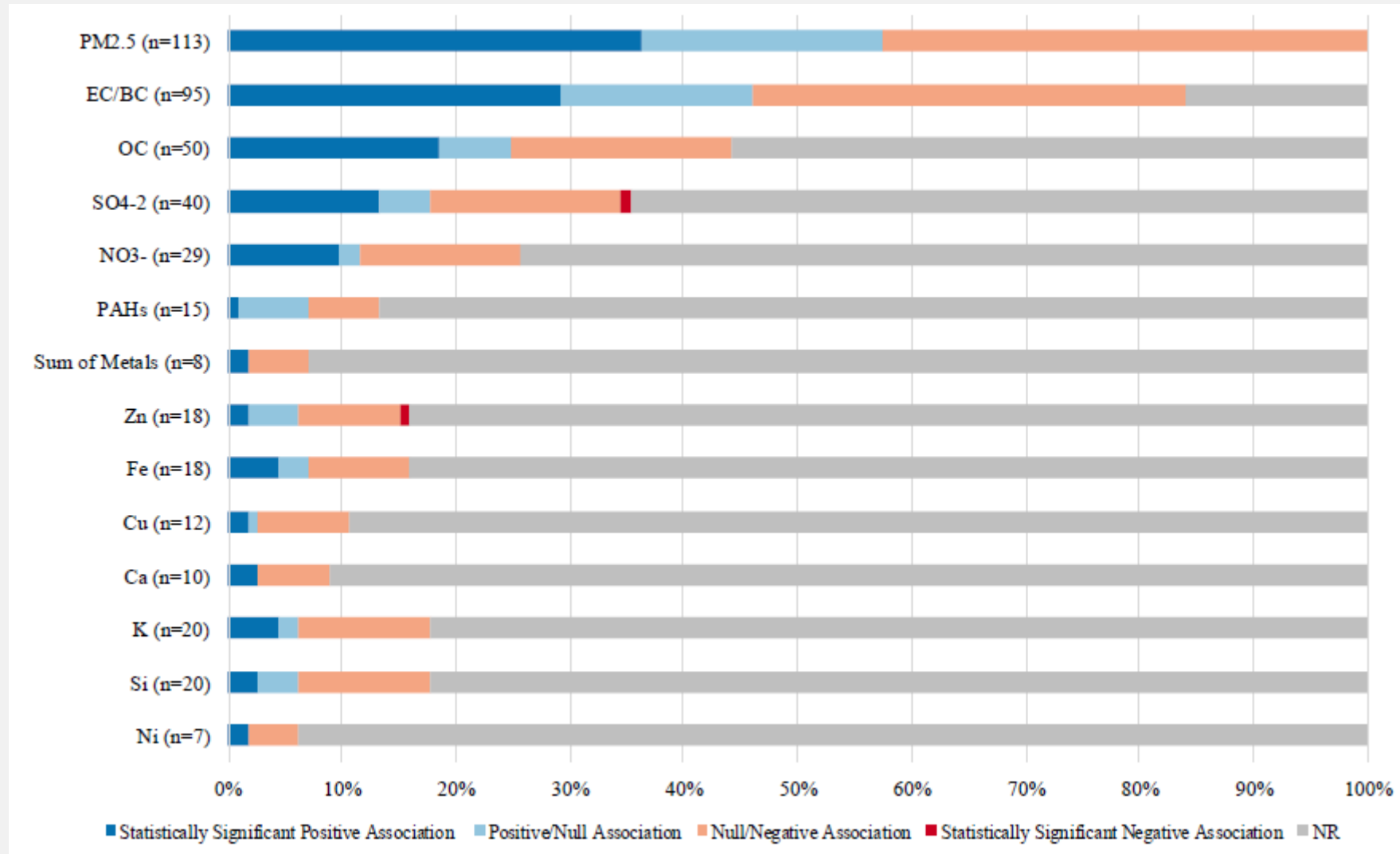


Figure 5-25. Distribution of associations for all respiratory effects and short-term PM_{2.5} mass and PM_{2.5} components exposure.

PM_{2.5} Components and Mortality

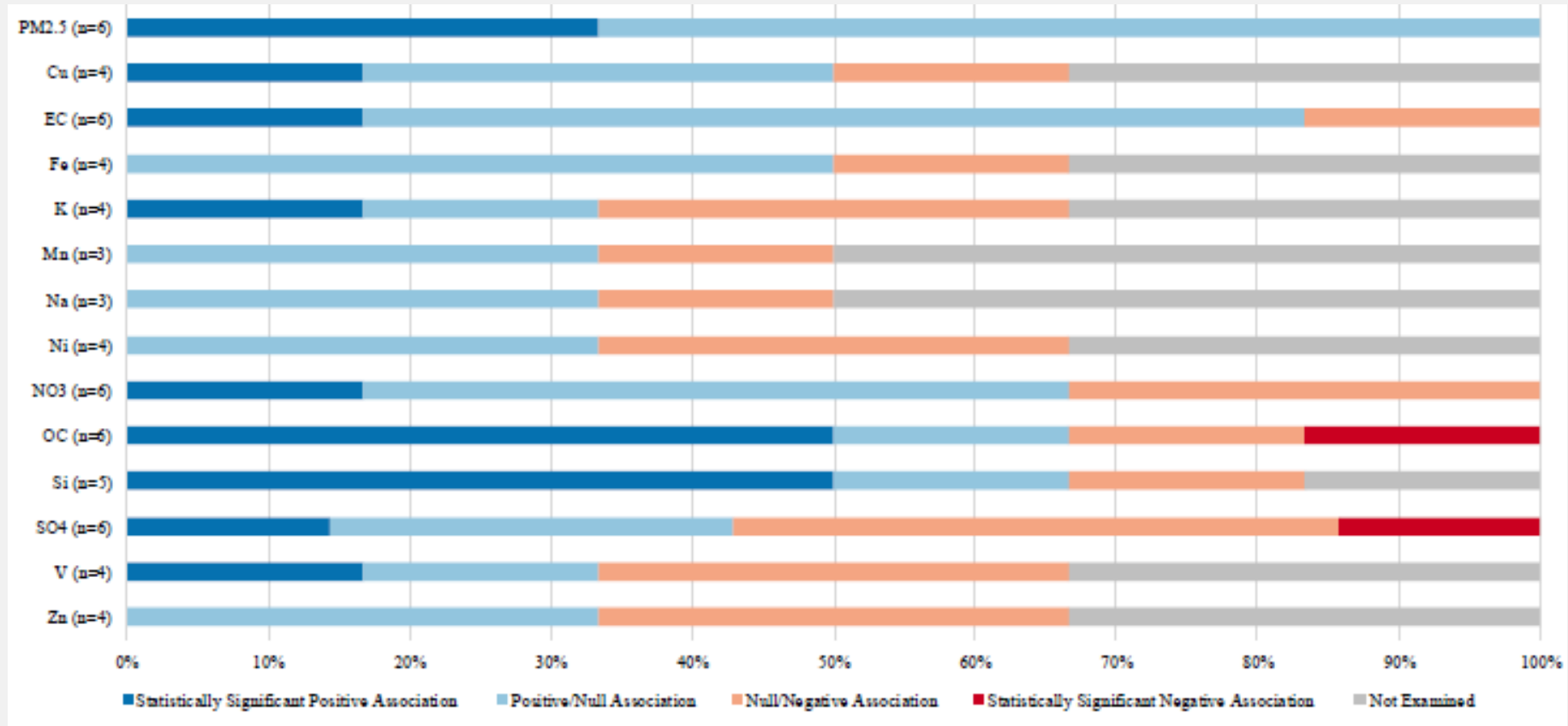


Figure 6-15. Distribution of total (nonaccidental) mortality associations for short-term PM_{2.5} and PM_{2.5} components exposure.

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

NONECOLOGICAL WELFARE EFFECTS		
ISA		Current PM Draft ISA
		PM
Welfare Effect	Visibility	
	Climate	
	Materials	
<p> Causal Likely causal Suggestive Inadequate </p> <p>* = new determination or change in causality determination from 2009 PM ISA</p>		

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.



Particulate Matter: Spotlight on Health Protection



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

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



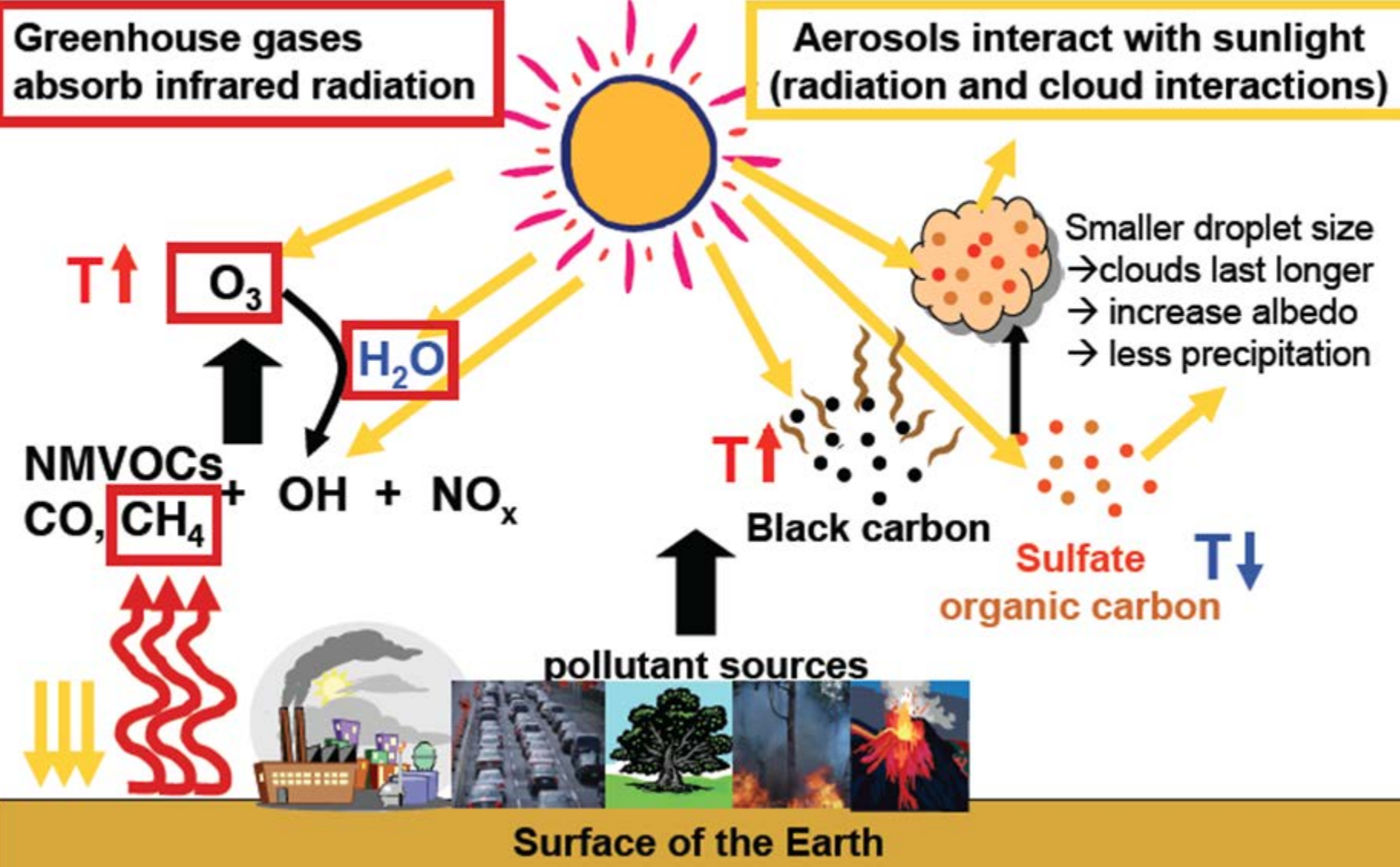
Overall Goal of this Presentation is to Address These Questions

- 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 NO₂ are major problems in California.
 - SO₂ 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 PM_{2.5} 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



Fine (PM_{2.5}) and ultrafine particles (UFP) are the most biologically active

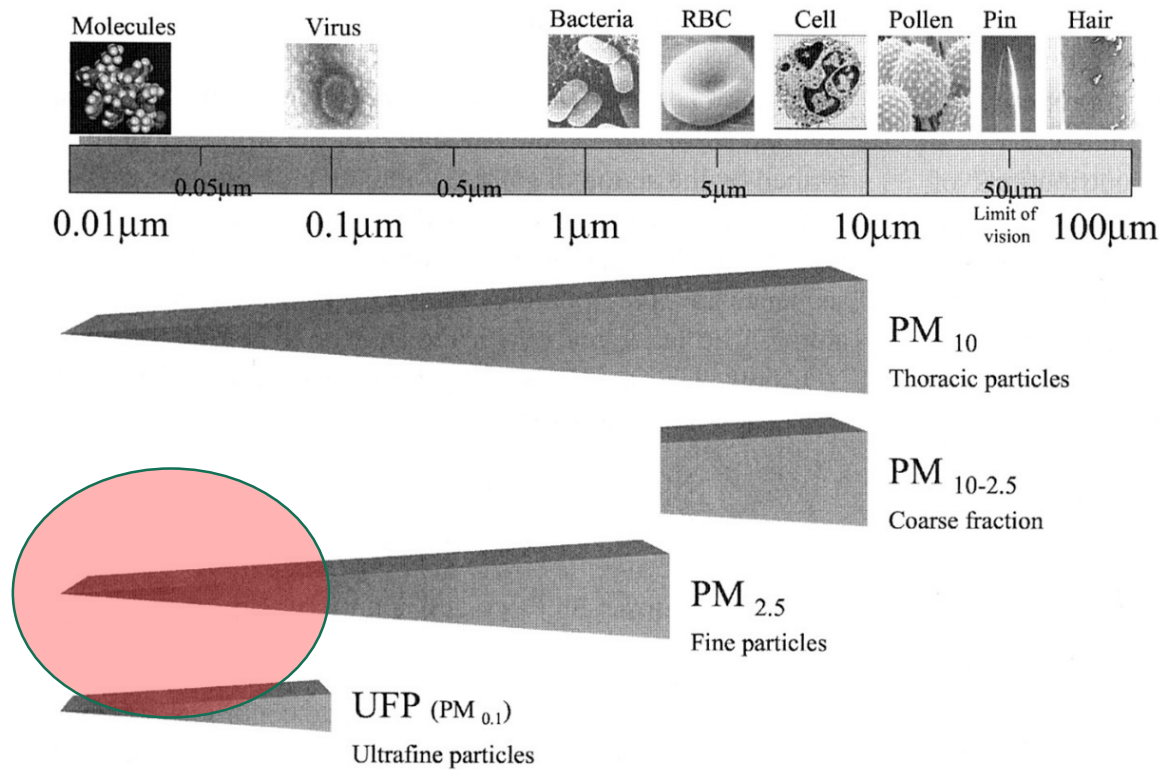


Figure 1. Particulate matter air pollution size distribution.

Combustion Sources Produce Toxic Air Contaminants

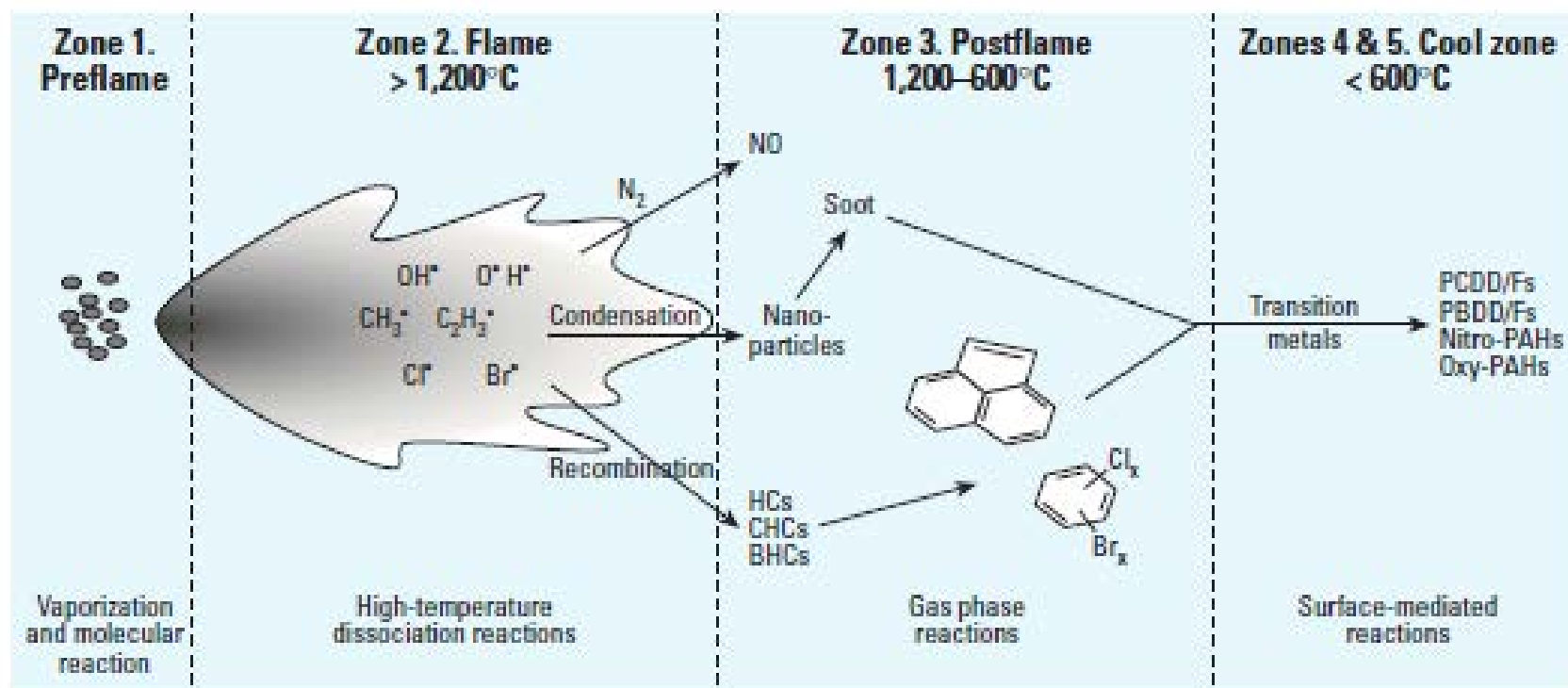


Figure 1. Combustor reaction zones. Zone 1, preflame, fuel zone; zone 2, high-temperature, flame zone; zone 3, postflame, thermal zone; zone 4, gas-quench, cool zone; zone 5, surface-catalysis, cool zone. PBDD/Fs, polybrominated dibenzo-*p*-dioxins and dibenzofurans. Reaction products from upstream zones 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.

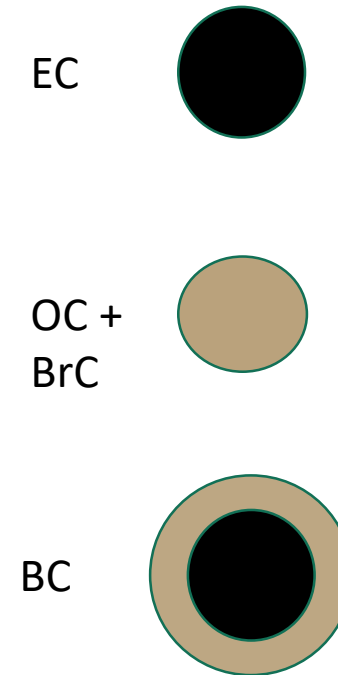
Origin and Health Impacts of Emissions of Toxic By-Products and Fine Particles from Combustion and Thermal Treatment of Hazardous Wastes and Materials

Stephanie A. Cormier,¹ Slawo Lomnicki,² Wayne Backes,³ and Barry Dellinger²

¹Department of Biological Science, and ²Department of Chemistry, Louisiana State University, Baton Rouge, Louisiana, USA; ³Department of Pharmacology, Louisiana State University Health Sciences Center, Baton Rouge, Louisiana, USA

PM_{2.5} 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 (CO₂).
- Organic carbon aerosols are a significant absorber of solar radiation. The absorbing part of organic aerosols is referred to as "brown" carbon (BrC).



1 in 6 deaths, worldwide, is attributable to Pollution

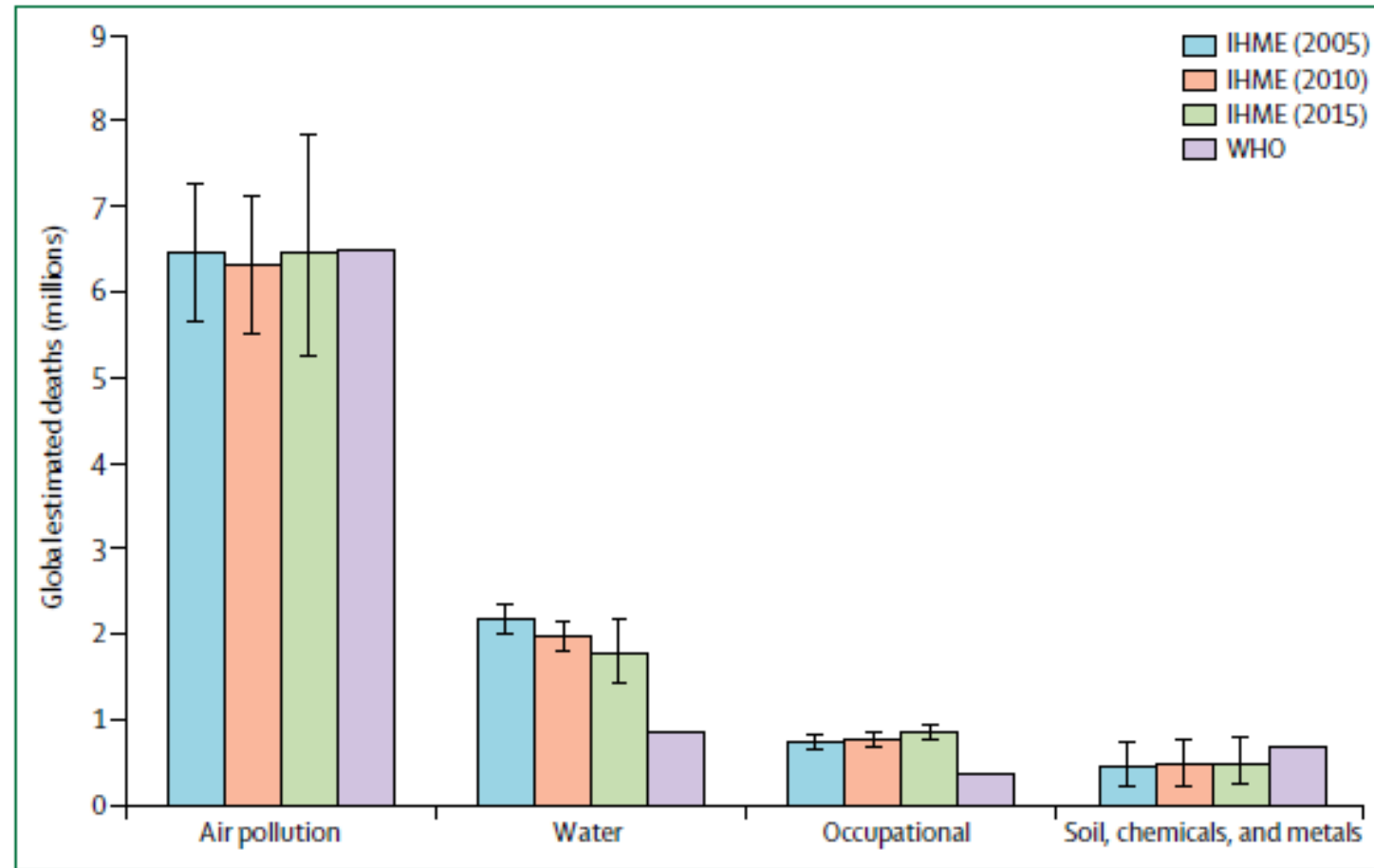


Figure 4: Global estimated deaths (millions) by pollution risk factor, 2005-15

Using data from the GBD study⁴⁷ and WHO.⁴⁹ IHME—Institute for Health Metrics and Evaluation.

Air Pollution Contributes to Multiple Diseases

The *Lancet* Commission on pollution and health, *Lancet*, October 2017

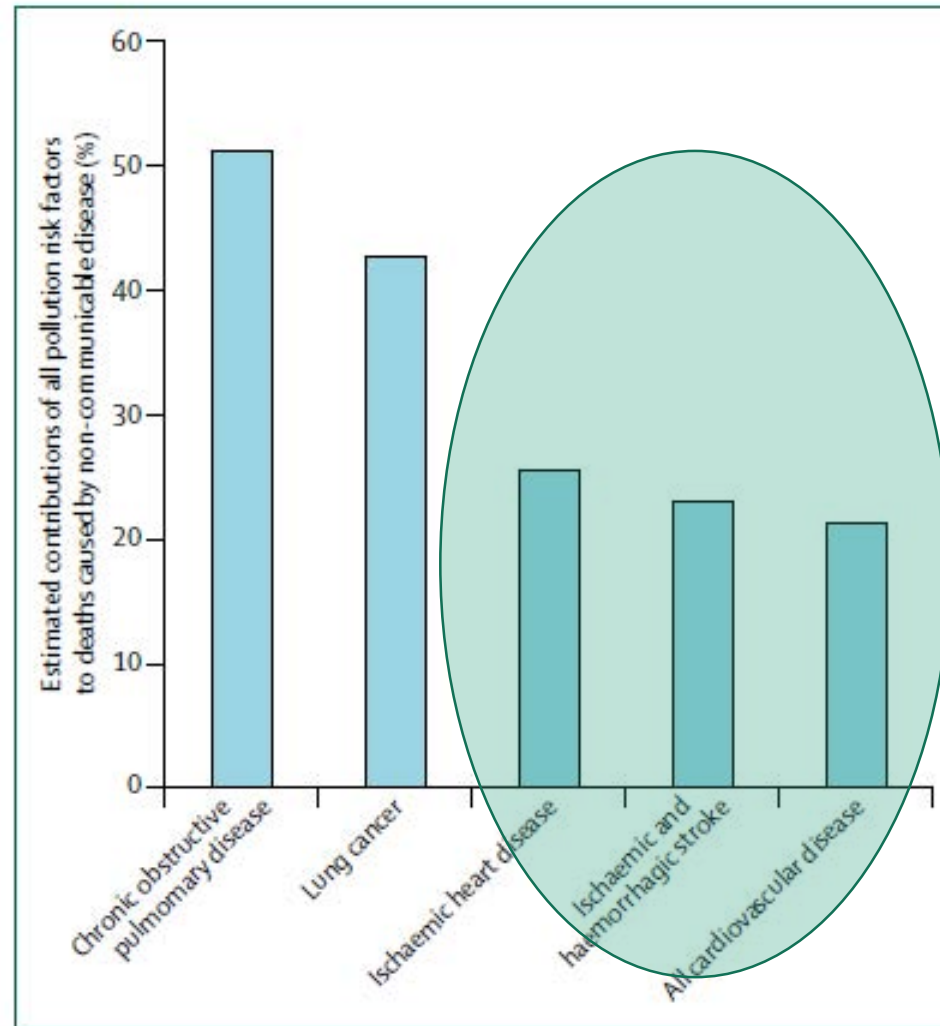
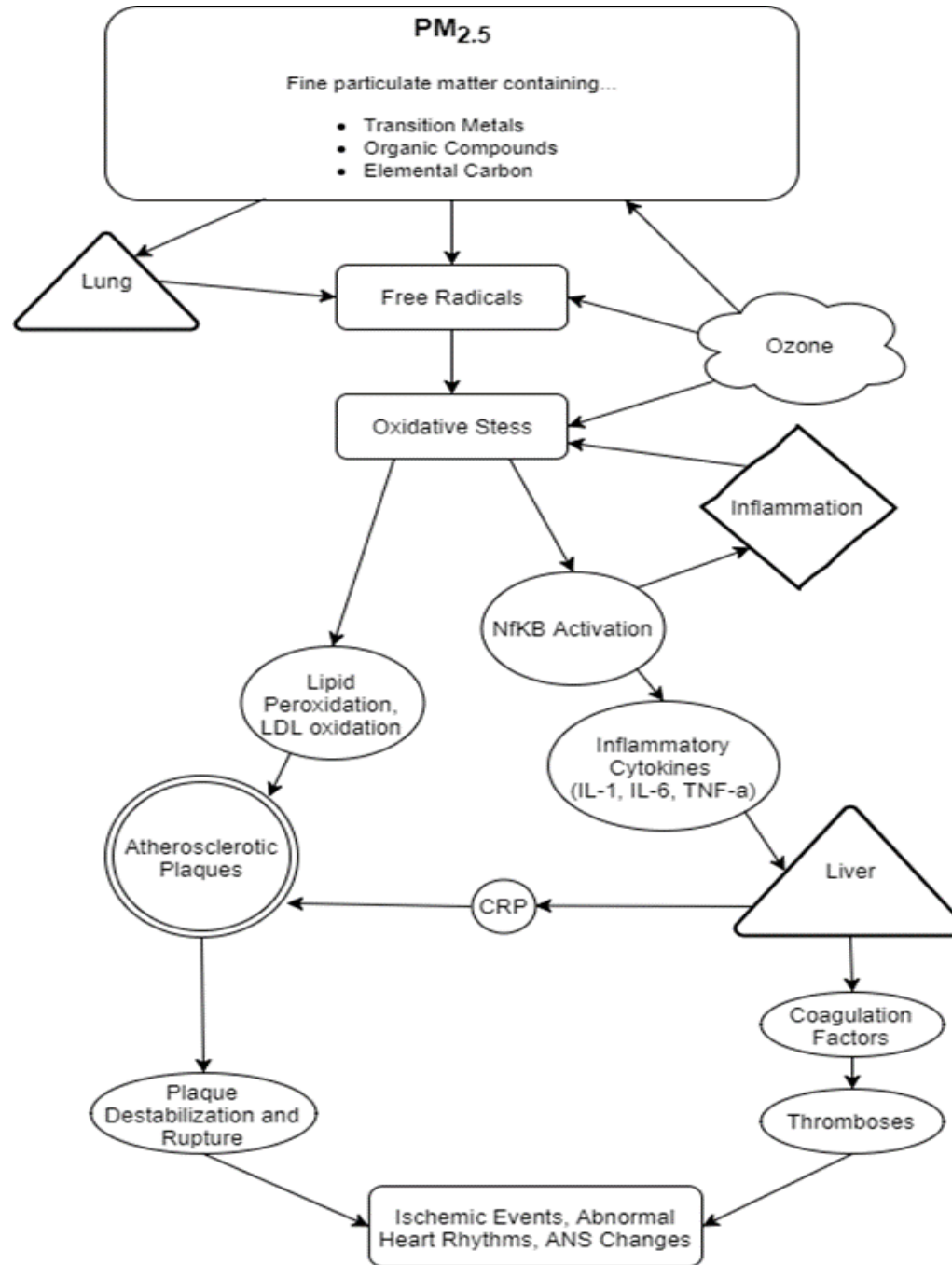
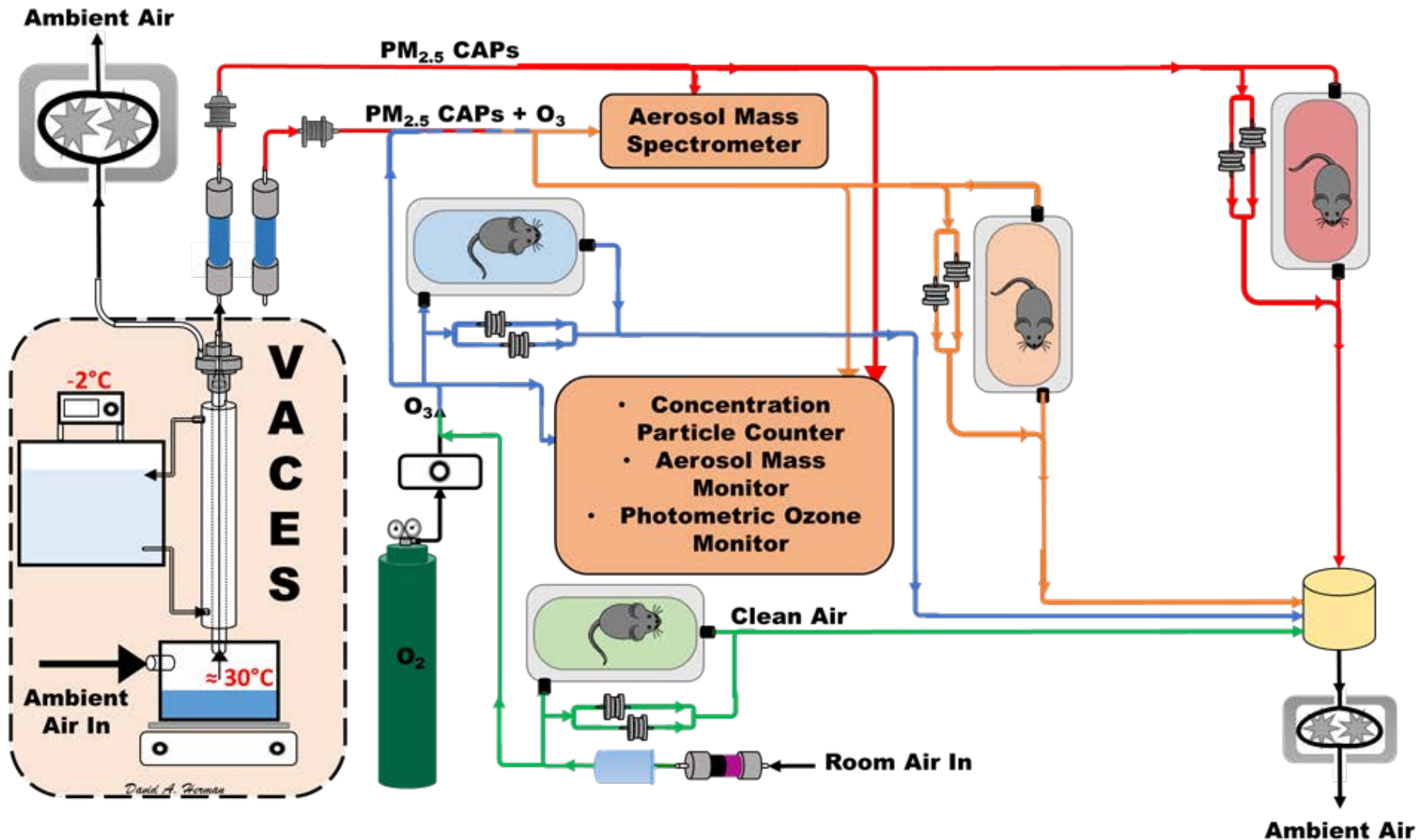


Figure 6: Estimated contributions of all pollution risk factors to deaths caused by non-communicable diseases, 2015
GBD Study, 2016.⁴⁷

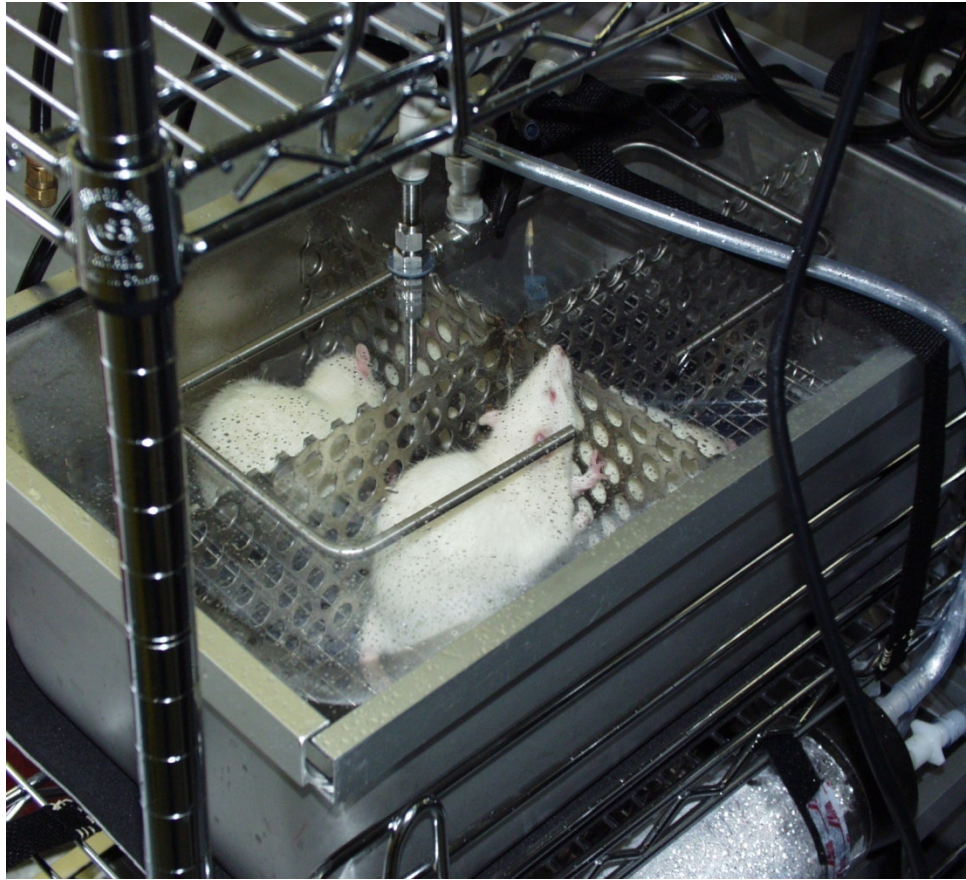
A Mechanistic Framework for PM_{2.5} Effects Leading to Cardiovascular Disease



We can examine the health effects of specific pollutants using controlled exposures and help understand the mechanisms by which PM causes or worsens cardiovascular diseases.



Rats or Mice Can
Be Exposed to
Purified Air or CAPs
in Sealed Chambers



The Sealed Chambers
Can Be Placed Onto
Racks to Facilitate
Transport



ECG and Blood Pressure Telemetry Devices can be Implanted to provide
physiology data before, during and after exposures.

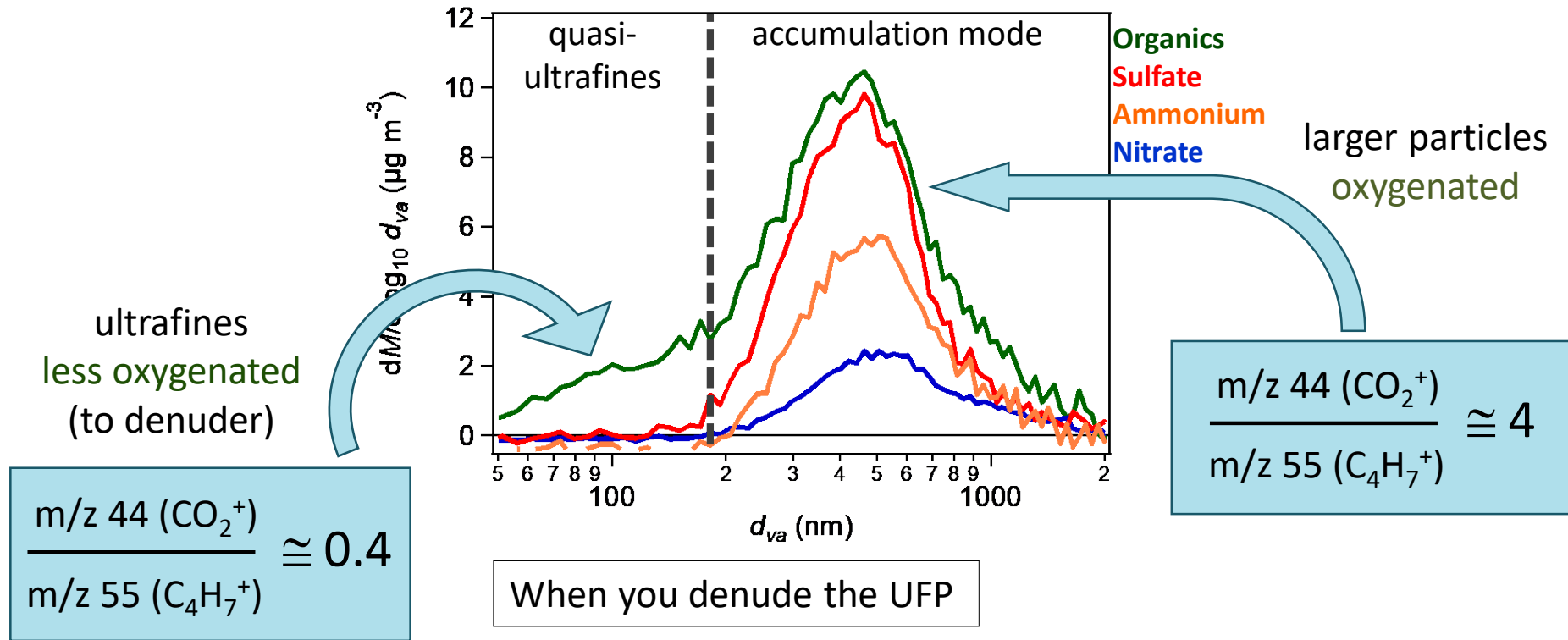
Exposure Protocol

- ApoE^{-/-} mice were surgically implanted with ECG telemetry devices.
- Mice were exposed 5 hr per day (8AM to 1 PM) 4 days per week for 8 weeks at UC Irvine and were housed in filtered air-supplied caging systems between exposures.
- ECG data were monitored during exposures and while the mice were in housing (21 hr / day).
- All animal protocols were approved by the Institutional Animal Care and Use Committee.

What Happens When You Denude Quasi-Ultrafine CAPs ($d_p < 180$ nm)?

- Particle number and mass are reduced.
- Refractory constituents, such as heavy metals and elemental carbon, were only marginally affected by heating.
- Labile species such as total and water soluble organic carbon and PAHs showed progressive loss in concentration with increase in TD temperature.

Health-related characteristics of Ultrafine PM



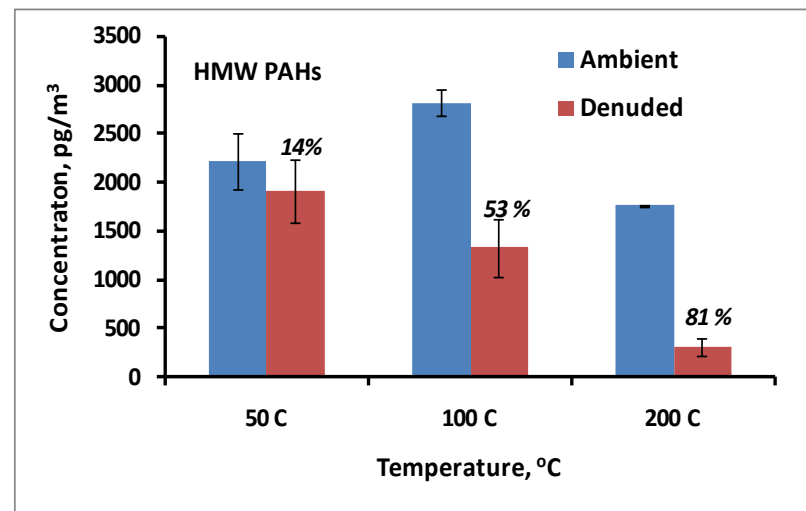
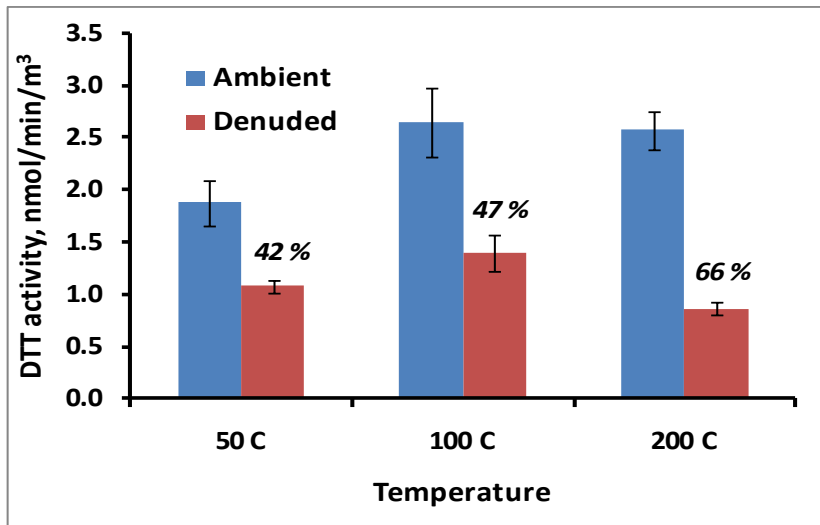
ultrafines less oxygenated (to denuder)

$$\frac{m/z\ 44\ (\text{CO}_2^+)}{m/z\ 55\ (\text{C}_4\text{H}_7^+)} \cong 0.4$$

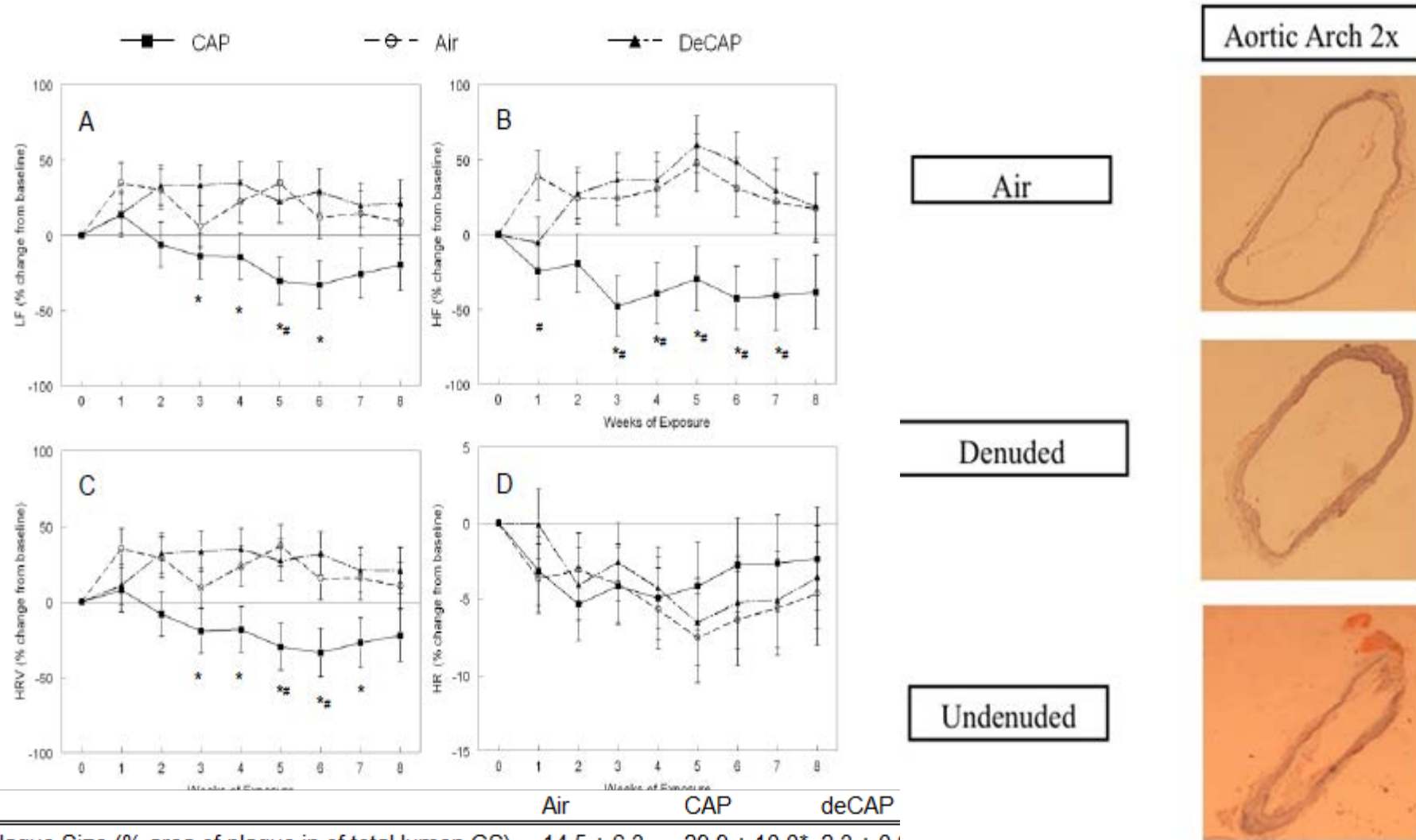
When you denude the UFP

larger particles oxygenated

$$\frac{m/z\ 44\ (\text{CO}_2^+)}{m/z\ 55\ (\text{C}_4\text{H}_7^+)} \cong 4$$

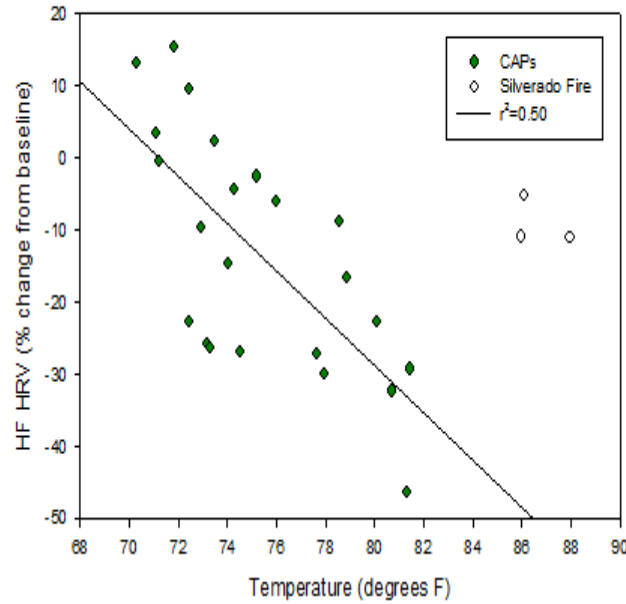


Removing the Organic Constituents From Ambient UFP Blocks CV Effects

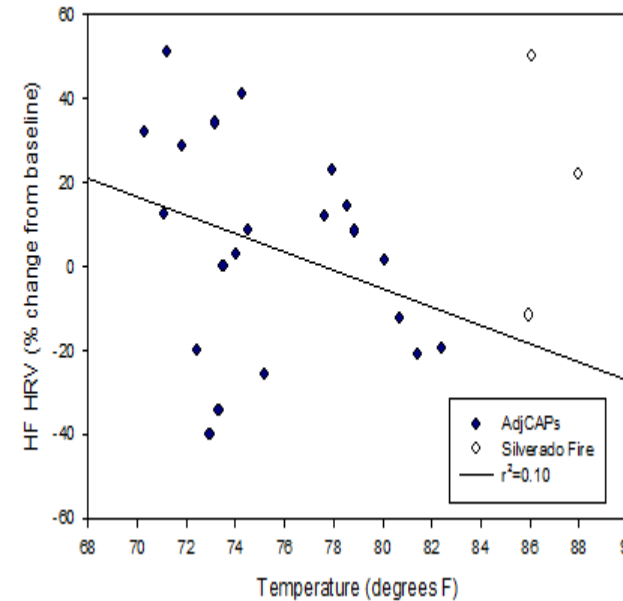
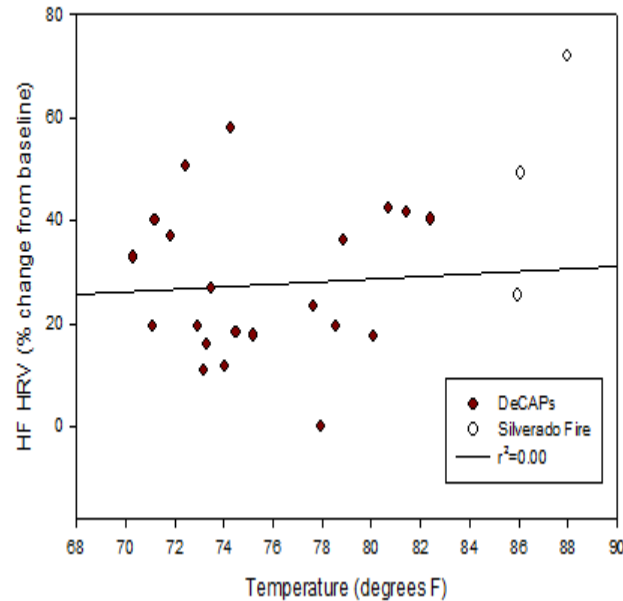
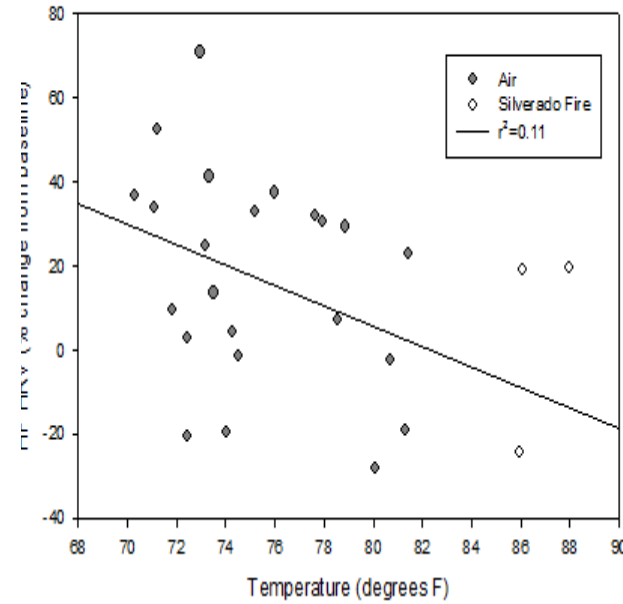


	Air	CAP	deCAP
Plaque Size (% area of plaque in of total lumen CS)	14.5 ± 6.3	29.9 ± 10.0*	2.3 ± 0.1
Lipid Accumulation (% area of lipid in total tissue CS)	5.1 ± 3.3	8.9 ± 2.4, #	2.2 ± 0.3
Lipid Peroxidation (nM MDA/mg protein)	134 ± 29	218 ± 32*,**	141 ± 17

Ambient Temp. vs HF HRV



Ambient Temp. vs HF HRV



These data show an association between ambient temperature and toxicity measured using heart rate variability (HRV).

The composition of the particles, which determines particle toxicity, is a function of atmospheric chemical reactivity, which is dependent on temperature and photochemical processes.

Conclusions

- PM exposures can exacerbate lung disease, heart disease and cancer
- UFP and PM_{2.5} contain toxic components and carcinogens
- Children, elderly and Individuals with pre-existing lung and heart conditions are at elevated risk
- The human studies and the toxicology studies support the premise that PM can be mechanistically and causally linked to cardiovascular health effects.

Funding Sources



- Research using advanced instrumentation (AMS and SMPS) was through AirUCI and funded by the National Science Foundation



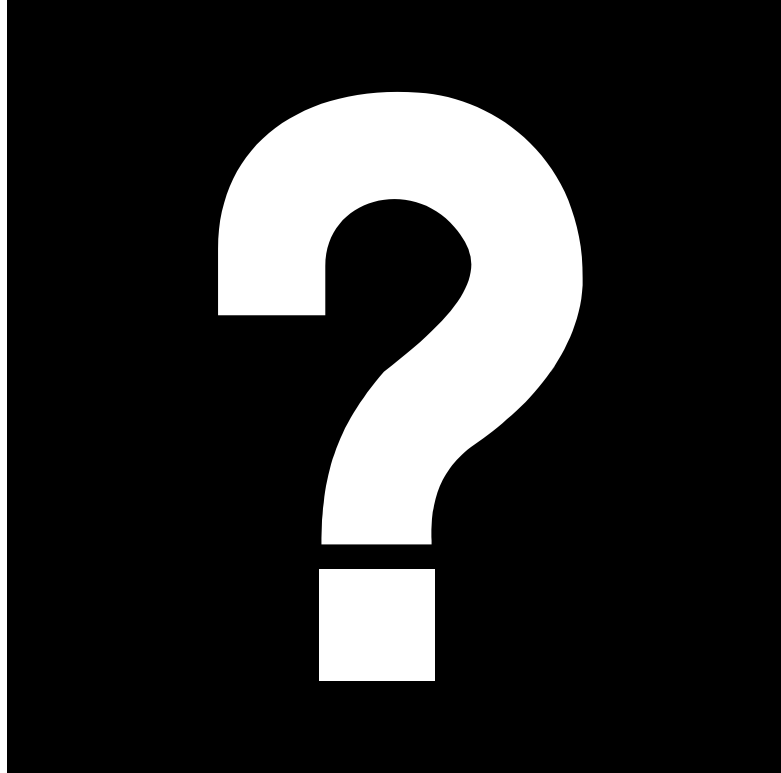
Moving the AMS is a group effort!



Health studies at are currently sponsored by the California Air Resources Board, the South Coast Air Quality Management District and the NIEHS



Questions and Discussion





Particulate Matter: Spotlight on Health Protection



John R. Balmes, M.D.

- Professor of Medicine at UC San Francisco
- Professor of Environmental Health Sciences in the School of Public Health at UC Berkeley
- Director of the Northern California Center for Occupational and Environmental Health
- Authored over 300 papers on occupational and environmental health-related topics
- Physician Member of the California Air Resources Board

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

John R. Balmes, MD
University of California,
San Francisco and Berkeley



Outline

- Particulate Pollution
 - What Do We Know
 - New Evidence
- Exposure Inequality
 - Cumulative Risk
- Wildfire PM
 - Cardiovascular Risk

Ambient Particulate Matter (PM)

- PM is a mixture, including particles of differing origin (combustion, crustal, biological) and varying size.
- Multiple sources
 - Ultrafines ($PM_{<0.1}$): Fuel (including biomass) combustion
 - $PM_{2.5}$: Fuel (including biomass) combustion
 - $PM_{10-2.5}$: Road dust, crustal, and biological material

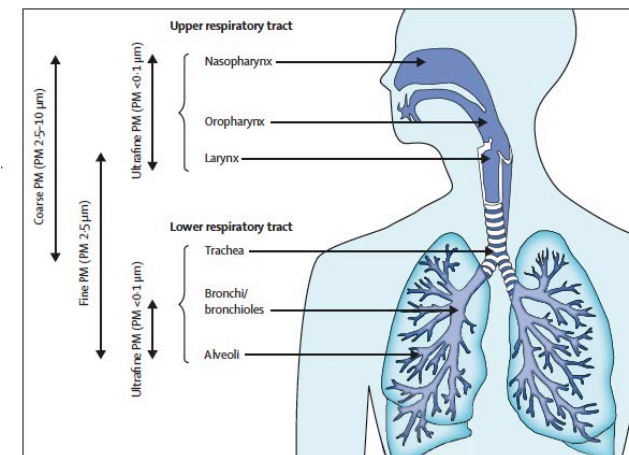
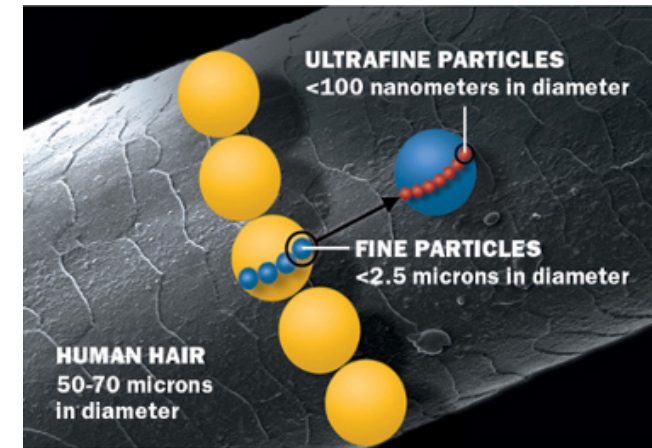


Figure 4: Compartmental deposition of particulate matter

Particulate Matter: Health Effects

- Asthma
 - Exacerbation
 - New-onset
- Decreased lung function growth
- Mortality
 - Ischemic heart disease
- Lung cancer

Key Questions

- Are current PM standards sufficiently protective?
 - No margin of safety
- How has the PM health evidence been strengthened?
 - New evidence of mortality effect at levels below the current NAAQS

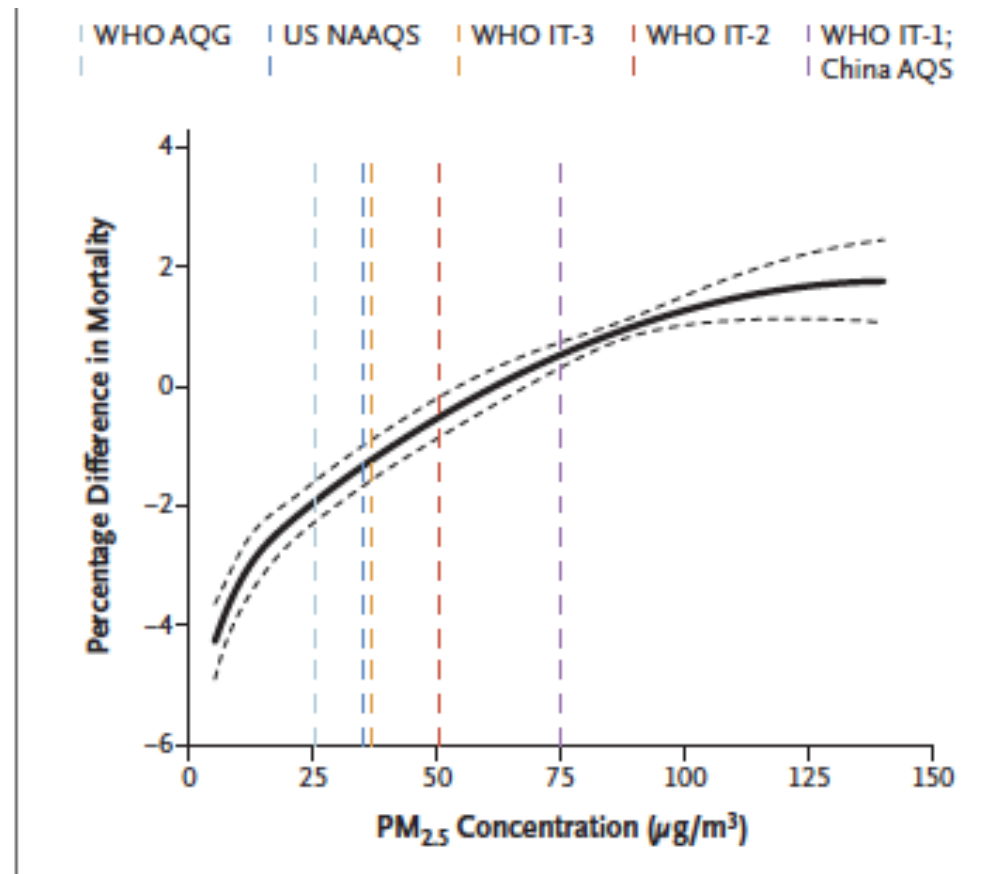
The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812

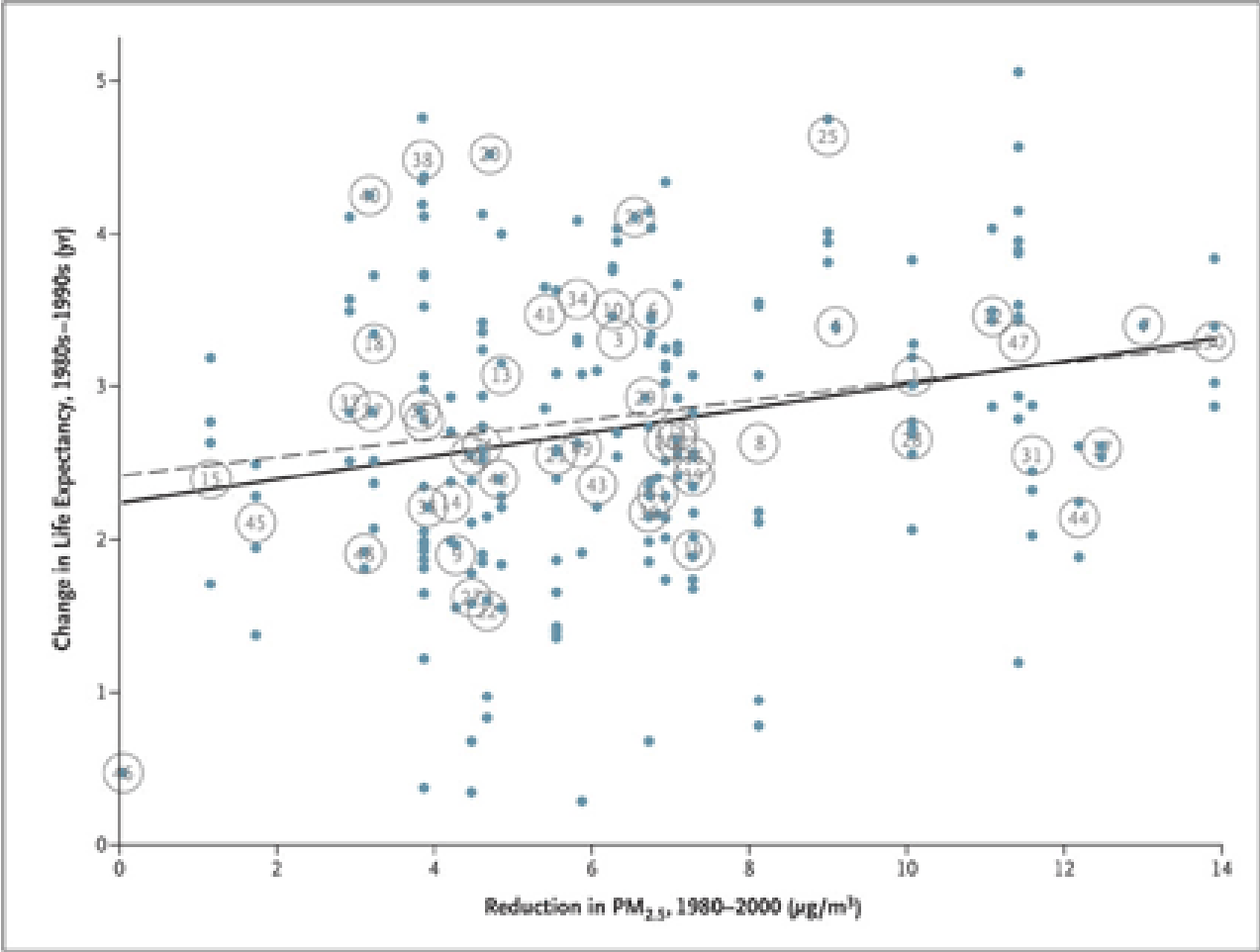
AUGUST 22, 2019

VOL. 381 NO. 8

Ambient Particulate Air Pollution and Daily Mortality in 652 Cities

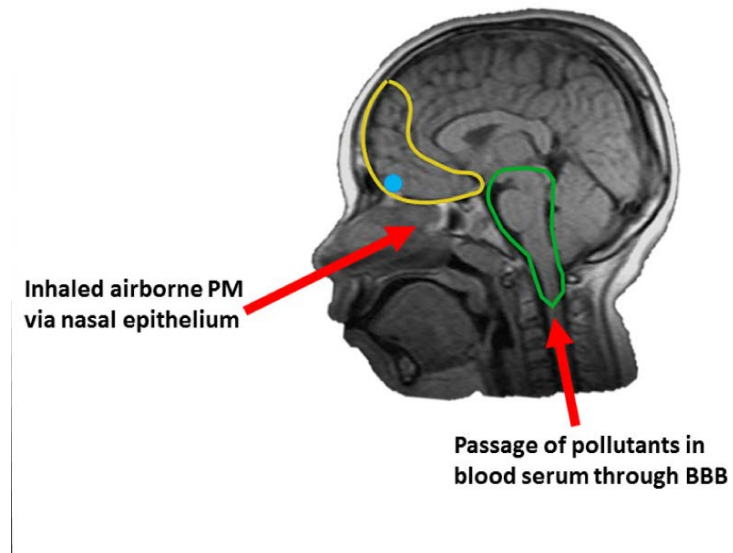


Fine-Particulate Air Pollution and Life Expectancy in the United States



Key Questions

- What new health effects are now recognized?
 - Adverse birth outcomes
 - Metabolic effects
 - Neurological effects



What is role of ultrafine particles (UFP)?

- UFP ($PM < 0.1\mu m$) are generated both as primary emissions from combustion processes and as secondary products of atmospheric chemistry
- Toxicological studies suggest UFP are a high-risk hazard, but epidemiological data are sparse because there is no monitoring network



Key Questions

- Are there “new” sensitive groups?
 - Children
 - People of color and low SES
- How should we account for **spatial scale of effects** (i.e., regional versus local-scale impacts, including proximity to major sources)?



Demographics of Children Living Near Freeways

- Children of color 3x more likely to live near high traffic density in California

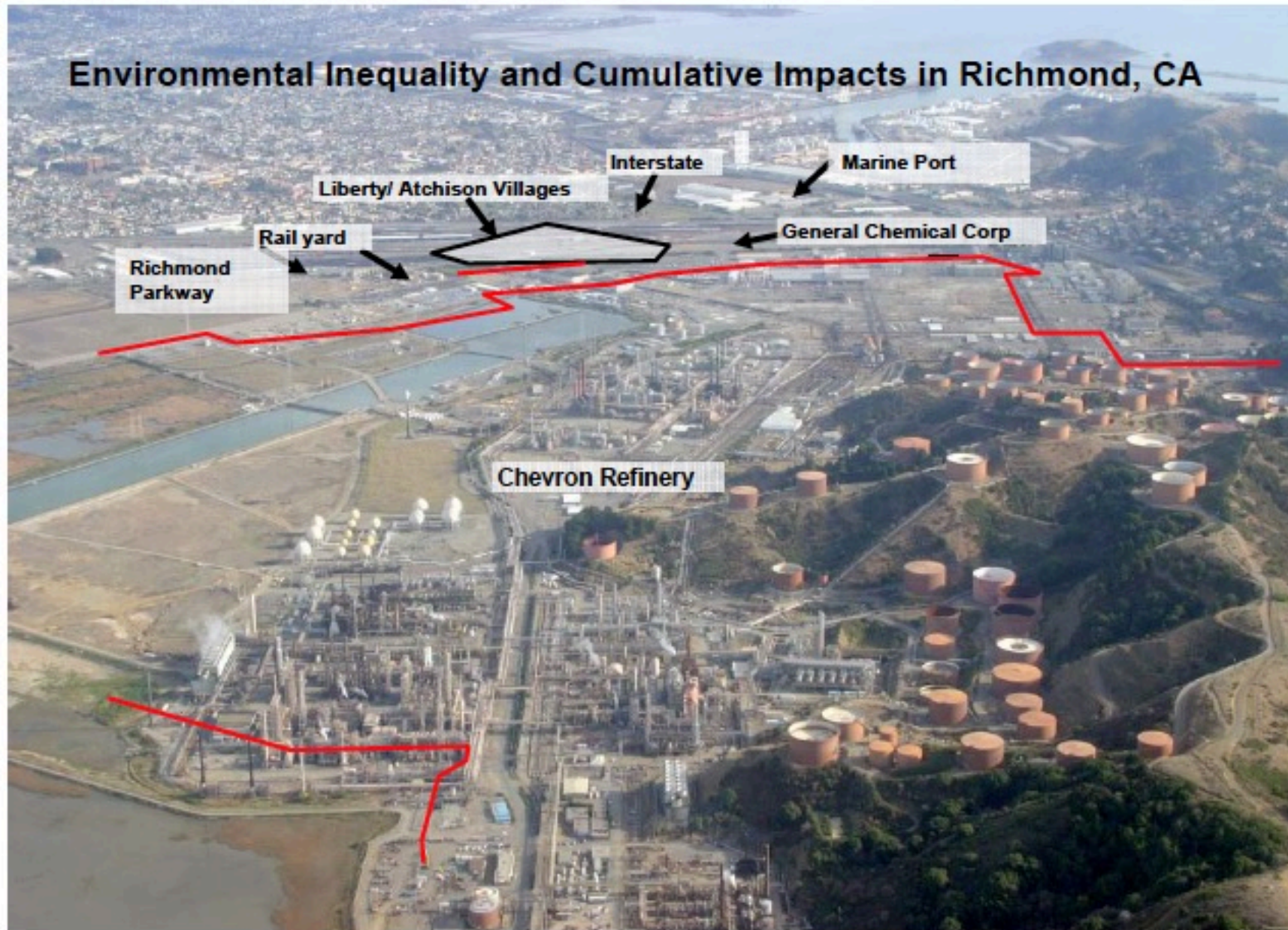
Gunier et al., California Dept of Health Services, 2003

- Schools near busy roads have a disproportionate number of children who are economically disadvantaged and non-white

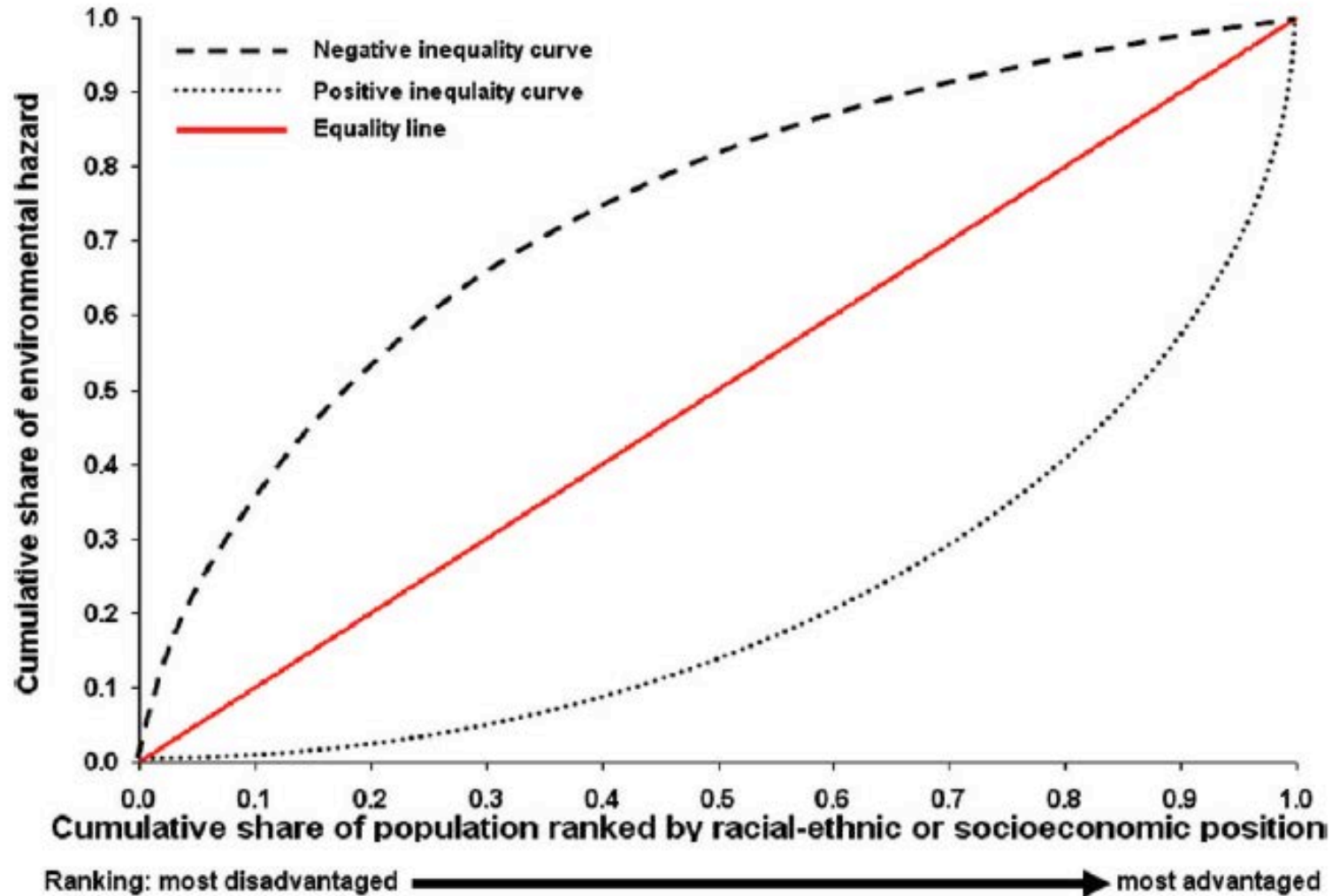
RS Green et al, Environ Health Perspect 2004;112:61.

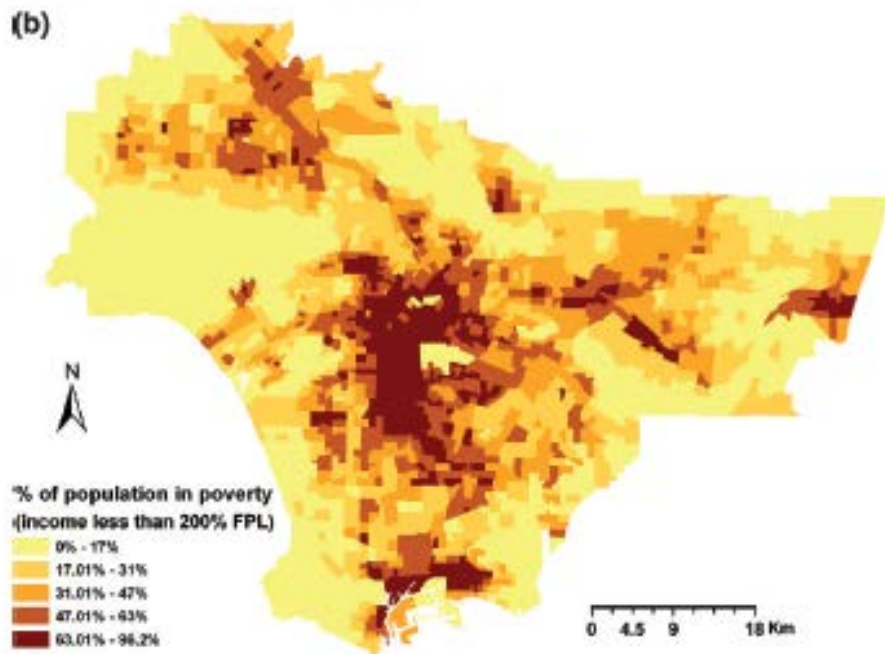
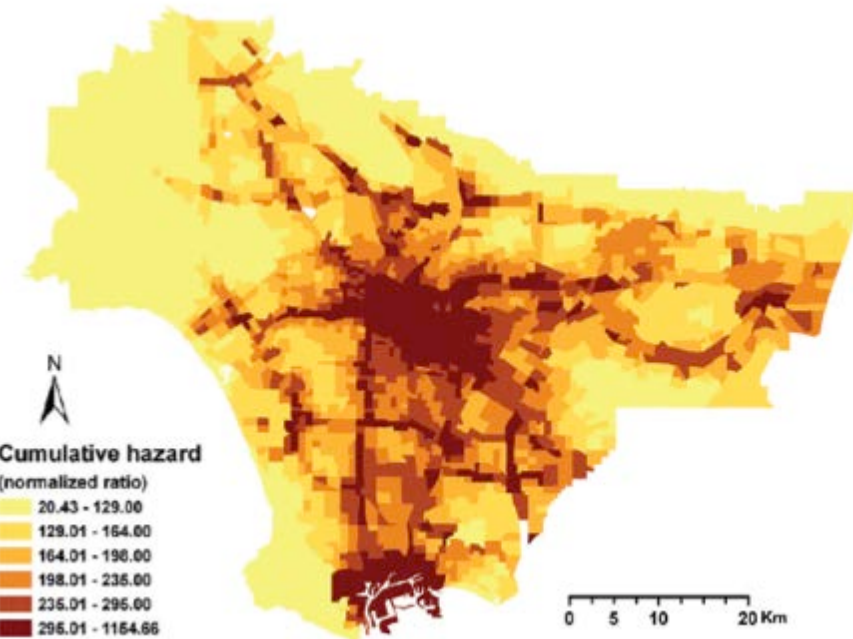
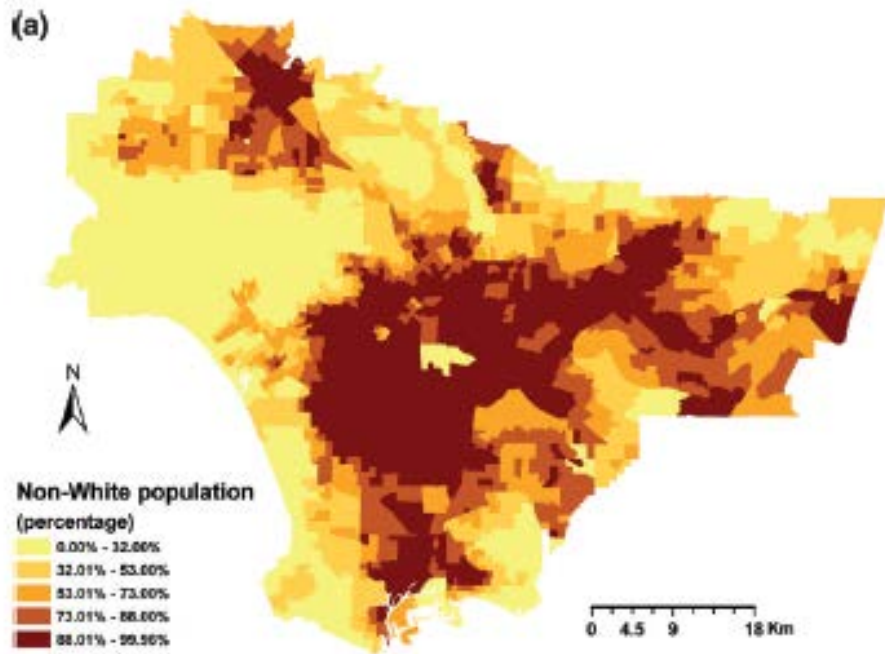


Environmental Inequality and Cumulative Impacts in Richmond, CA



Inequality Curve





Environ Sci Technol 2009;43:7626–34.

Cumulative Risk

- People of color and low SES have
 - Greater exposures to outdoor particulate pollution
 - Disproportionate proximity to polluting land uses and toxic emissions
- Poor communities have more health-damaging factors and less health-promoting amenities
 - Less access to healthy food and health care
 - Less green space and recreational programs
 - Poor quality housing and greater violence

Key Questions

- What are health impacts of **high-concentration acute events** (e.g., wildfires)? How should we compare them to day-to-day PM impacts?

Clear evidence of an association between wildfire smoke and respiratory health

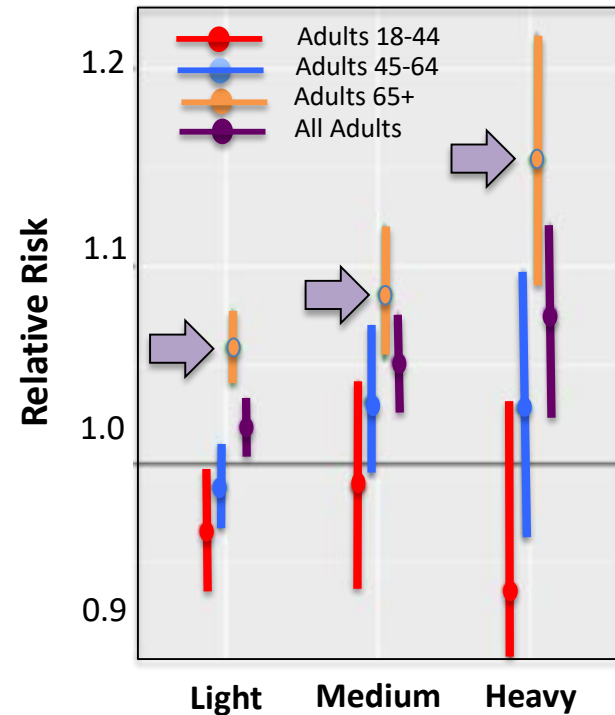
- Asthma exacerbations significantly associated with higher wildfire smoke ***in nearly every study***
- Exacerbations of chronic obstructive pulmonary disease (COPD) significantly associated with higher wildfire smoke in most studies
- Growing evidence of a link between wildfire smoke and respiratory infections (pneumonia, bronchitis)



Wildfire-PM_{2.5} Increases Heart Attack & Stroke

- **Wildfire-PM_{2.5} associated with heart attacks and strokes for all adults, particularly for those over 65 years old**
- **Increase in risk the day after exposure:**
 - All cardiovascular, 12%
 - Heart attack, 42%
 - Heart failure, 16%
 - Stroke, 22%
 - All respiratory causes, 18%
 - Abnormal heart rhythm, 24%
(on the same day as exposure)

All Cardiovascular Causes



80

Thank you



Particulate Matter: Spotlight on Health Protection



H. Christopher Frey, Ph.D., F. A&WMA, F. SRA

- Glenn E. Futrell Distinguished University Professor of Environmental Engineering in the Department of Civil, Construction, and Environmental Engineering at North Carolina State University
- Adjunct professor in the Division of the Environment and Sustainability at the Hong Kong University of Science and Technology
- Fellow of the Air & Waste Management Association and of the Society for Risk Analysis
- Ph.D. in Engineering and Public Policy from Carnegie Mellon

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

H. Christopher Frey
frey@ncsu.edu

NC STATE UNIVERSITY

Department of Civil, Construction & Environmental Engineering
North Carolina State University
Raleigh, NC 27695

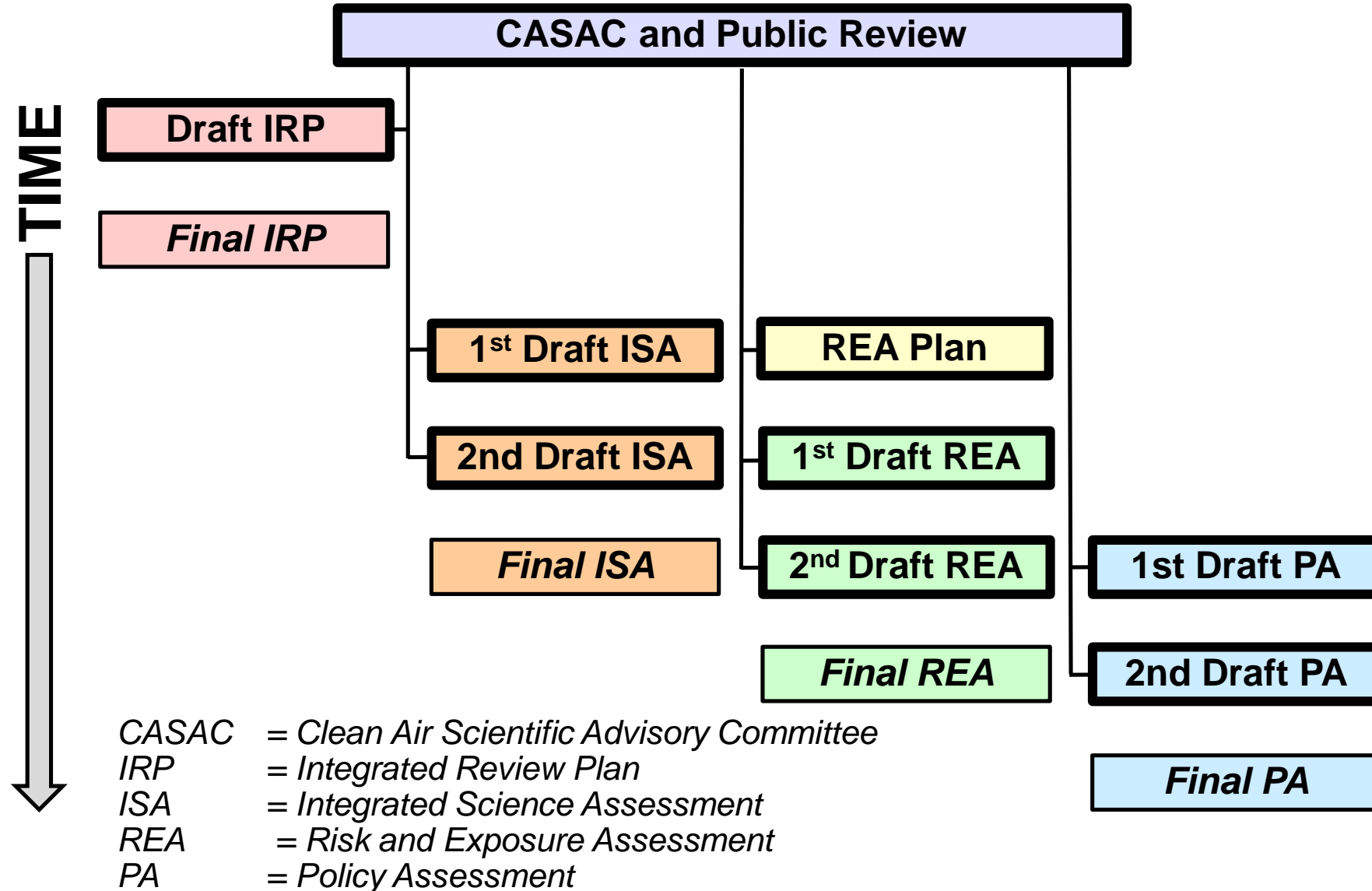
Presented at:
Particulate Matter: Spotlight on Health Protection
Bay Area Air Quality Management District
San Francisco, CA

October 28, 2019

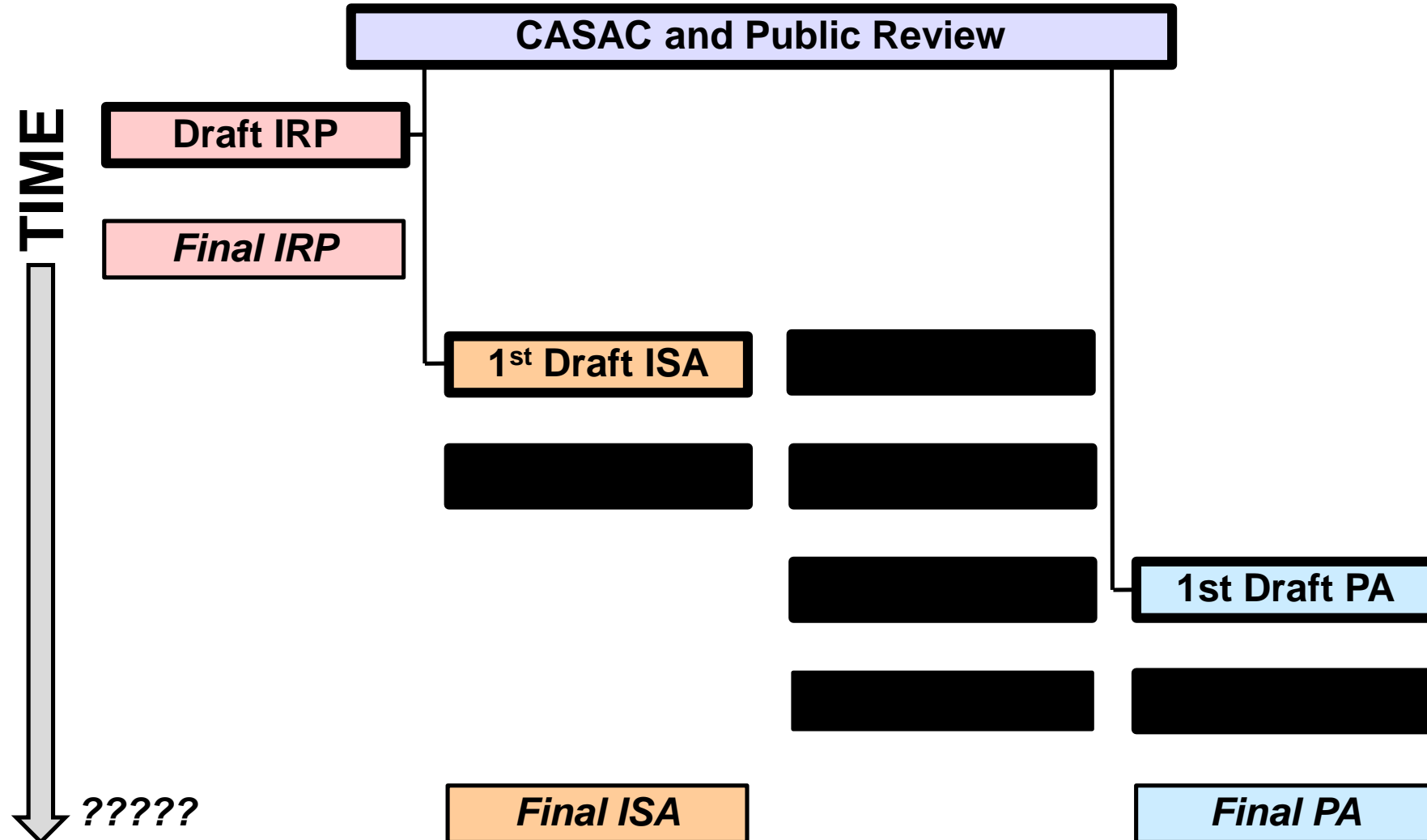
Key Points

- The National Ambient Air Quality Standard (NAAQS) Science Review Process Worked Well Until 2017
- EPA Administrators Pruitt and Wheeler Have Broken the Process
- Particulate Matter Science Review By the EPA Clean Air Scientific Advisory Committee (CASAC) is Highly Deficient: Appropriate to Look Elsewhere
- Disbanded CASAC PM Review Panel Reconvened Itself
- Key Findings of the Independent Particulate Matter Review Panel

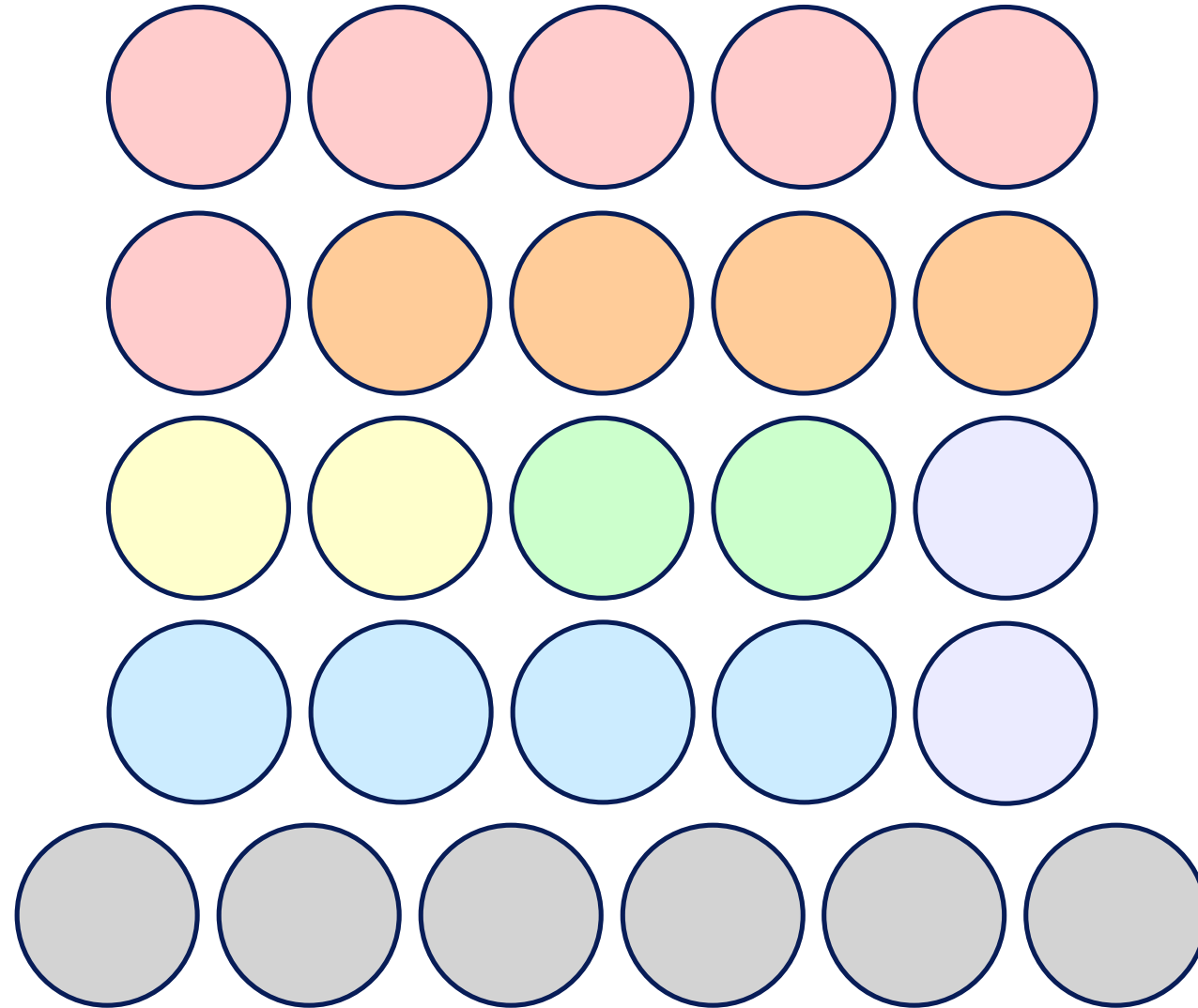
Generic “Full” National Ambient Air Quality Standard (NAAQS) Science Review from Document Perspective



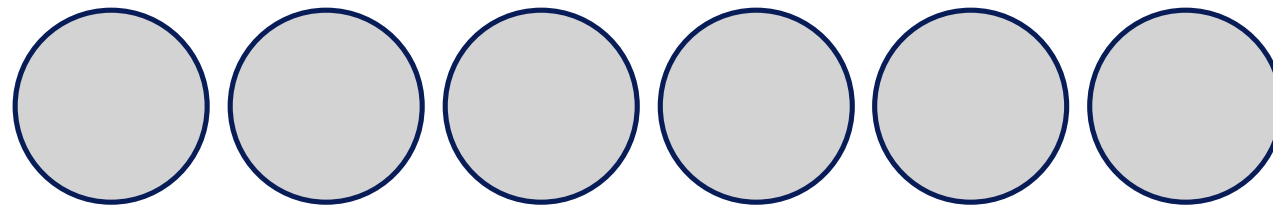
Pruitt/Wheeler (P/W) Particulate Matter NAAQS Science Review from Document Perspective



2015 EPA CASAC Particulate Matter Review Panel (26)



Pruitt/Wheeler EPA CASAC Particulate Matter Review Panel (6 last week, 7 by statute)



The Latest from CASAC, as of 2:25 pm Friday, October 25, 2019



There Should be 26
People at This Table, Not
6 (one is EPA staff)

The Latest from CASAC, as of 2:25 pm Friday, October 25, 2019

- CASAC is split 4-2:
 - Four recommend keeping all current standards (primary PM_{2.5}, coarse PM, secondary PM_{2.5}) as is.
 - Rationales offered for keeping the annual primary PM_{2.5} standard are ill-informed or inappropriate, given the state of the science, lack of needed expertise and obvious lack of understanding of the statutory mandate of the Clean Air Act.

Independent Particulate Matter Review Panel

- Formerly the CASAC PM Review Panel
- Disbanded October 10, 2018
- Met October 10, 2019 to October 11, 2019 in Crystal City, VA
- Follow-up Teleconference October 18, 2019 to finalize report



Independent Particulate Matter Review Panel

- **Dr. H. Christopher Frey**, Chair, North Carolina State University
- **Dr. Peter Adams**, Carnegie Mellon University
- **Dr. John L. Adgate**, Colorado School of Public Health
- **Mr. George Allen**, NESCAUM
- **Dr. John Balmes**, University of California at San Francisco
- **Dr. Kevin Boyle**, Virginia Tech
- **Dr. Judith Chow**, Desert Research Institute
- **Dr. Douglas W. Dockery**, Harvard T.H. Chan School of Public Health
- **Mr. Dirk Felton**, NY State Dept. of Environmental Conservation
- **Dr. Terry Gordon**, New York University School of Medicine
- **Dr. Jack Harkema**, Michigan State University
- **Dr. Joel Kaufman**, University of Washington
- **Dr. Patrick Kinney**, Boston University School of Public Health
- **Dr. Michael T. Kleinman**, University of California at Irvine
- **Dr. Rob McConnell**, University of Southern California
- **Mr. Richard Poirot**, Independent Consultant
- **Dr. Lianne Sheppard**, University of Washington
- **Dr. Jeremy Sarnat**, Rollins School of Public Health, Emory University
- **Dr. Barbara Turpin**, University of North Carolina at Chapel Hill
- **Dr. Ronald Wyzga**, Retired, Electric Power Research Institute

Independent Particulate Matter Review Panel

- Followed the same process and procedures as we did formerly as the CASAC PM Review Panel
- Developed a letter to the EPA Administrator and Consensus Responses to EPA Charge Questions on the Draft Policy Assessment
- Submitted our report to CASAC, the docket, and the Administrator
- ucsusa.org/pmpanel



Acknowledgment of EPA Staff

- The Panel finds that the EPA staff in the Office of Air Quality Planning and Standards have undertaken a good faith effort to produce a first draft of the PA.
- This draft was produced under extenuating, unprecedented, and inappropriate constraints.
- **The Panel commends the staff for this effort.**

Causality Determinations

- The **weight of evidence framework for causality determination** that is applied by EPA is an **appropriate and well-vetted tool** for drawing causal conclusions.
- The epidemiologic **evidence**, supported by evidence from controlled human studies and toxicological studies, **supports the ‘causal’ and ‘likely to be causal’ determinations** that are the focus of the draft PA.
- “The epidemiologic **evidence** provides strong scientific **support for recommendations** regarding current and alternative standard levels.”
- **Arguments to retain the current primary PM_{2.5} standards** “would require disregard of the epidemiological evidence,” and “are not scientifically justified and **are specious.**”

Major Findings: Fine Particle Standards

- The current primary fine particle (PM_{2.5}) annual and 24-hour standards are **not protective of public health**.
- Retain current indicators, averaging times, and forms.
- The **annual** standard should be **10 µg/m³ to 8 µg/m³** (versus 12 µg/m³ now).
- The **24-hour** standard should be **30 µg/m³ to 25 µg/m³** (versus 35 µg/m³ now).
- **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**.
- **Supported** by research from **experimental models** in animals and humans and by **accountability studies**

Major Findings: Fine Particle Standards

- A motivation for strengthening the 24-hour PM_{2.5} standard is high 24-hour to annual ratios related to **residential wood combustion** in some areas.
- Panel notes **growing frequency and severity of so-called “wildfires.”**

Accounting for Limitations

- The Panel considered in detail uncertainties and limitations of available epidemiologic evidence, such as:
 - Use of linear, multipollutant models
 - Possibility that co-pollutants may be effect modifiers rather than confounders
 - Confounding by individual characteristics has been considered and evaluated
 - No rationale or empirical support for confounding by temperature in annual studies
- Consistency among **multiple multicity models**, for which there is variability in relative ambient **mixtures of co-pollutants, population demographics, climatic zones**, and distributions of **housing characteristics**, supports the **robustness** of their results.

Recommended Range for Annual PM_{2.5} Standard

- At **10 µg/m³** there is a **very high degree of scientific confidence** in the relationship between exposure to fine particles and **adverse effects**.
- The risk is **linear** with **no threshold** below the current standard down to an annual level of 8 µg/m³ or lower.
- The Panel finds that there is **not sufficient scientific certainty below 8 µg/m³** to support a lower recommendation.

Other Issues: At Risk Groups

- Di et al. (2017a) chronic Medicare study shows that the relative risk for African Americans is three times higher than that of the entire population (hazard ratio of 1.21 per 10 $\mu\text{g}/\text{m}^3$ increase in $\text{PM}_{2.5}$).

BAAQMD's Questions

- Are current PM standards sufficiently protective? **Emphatic NO – definitely not for PM_{2.5}.**
- How has the PM health evidence been strengthened? **Better “exposure” models, much larger study populations at much lower levels than before.**
- What new health effects are now recognized? **Strengthening of some causality determinations, but largely the focus is still premature mortality, respiratory morbidity, and cardiovascular morbidity.**
- New endpoints like cancer and central nervous system effects? **Opinions differ.**
- New sensitive groups, like children and lower socioeconomic status, SES, populations? **Growing recognition of “at risk” groups.**
- Are all types of PM equal? **Probably not.** Or, are some more dangerous than others? **Probably. But, more work needed. No components are as yet ‘exonerated.’**
- How severe are PM health risks? **Premature mortality is severe.**
- What additional health benefits can be achieved by further reducing PM to below current standards? **Difficult to quantify with certainty but on the order of tens of thousands of deaths nationally.**

BAAQMD's Questions

- How important are short-term PM events, like wildfires? **Not well-known scientifically but of concern for potential or anticipated effects. Research recommended.**
- How should we weight them in comparison with ongoing day-to-day PM levels? **No simple answer. Depends... can they be controlled? If so, how? Via a state implementation plan? And would you slap non-attainment on an area just devastated by a wildfire?**
- How important are ultrafine particles, UFPs? **Current evidence of adverse effects is generally weak but there is concern for potential or anticipated effects. Need more monitoring to support more epidemiological studies. Panel recommends a UFP FRM for this purpose.**
- Should we consider more than just PM mass? (*meaning particle number concentration?*) **In research, absolutely. In regulation, too soon, unless one takes a very precautionary, highly risk-averse decision approach.**
- Which is most protective, an annual average target or a 24-hour average one? Or, a sub-daily average? **For most parts of the country, annual can offer protection also for 24-hour averages. For other parts, not so. Panel comments on this. Health data on sub-daily is too limited as yet to support a standard at the national level, but Panel has recommendations to look at this further.**

Next Steps

- CASAC will release its draft report on the draft PM Policy Assessment within a few weeks.
- CASAC will meet on December 3, 2019 to review and likely finalize its report to the Administrator
- Opportunity for public comment in writing beforehand and oral comment at the meeting.
- *CASAC will review the draft ISA and draft PA for Ozone at the Dec 3-6, 2019 meeting.*

Key Points

- The NAAQS Science Review Process Worked Well Until 2017
- EPA Administrators Pruitt and Wheeler Have Broken the Process
- Particulate Matter Science Review By CASAC is Highly Deficient: Appropriate to Look Elsewhere
- Disbanded CASAC PM Review Panel Reconvened Itself
- Key Findings of the Independent Particulate Matter Review Panel

Acknowledgments

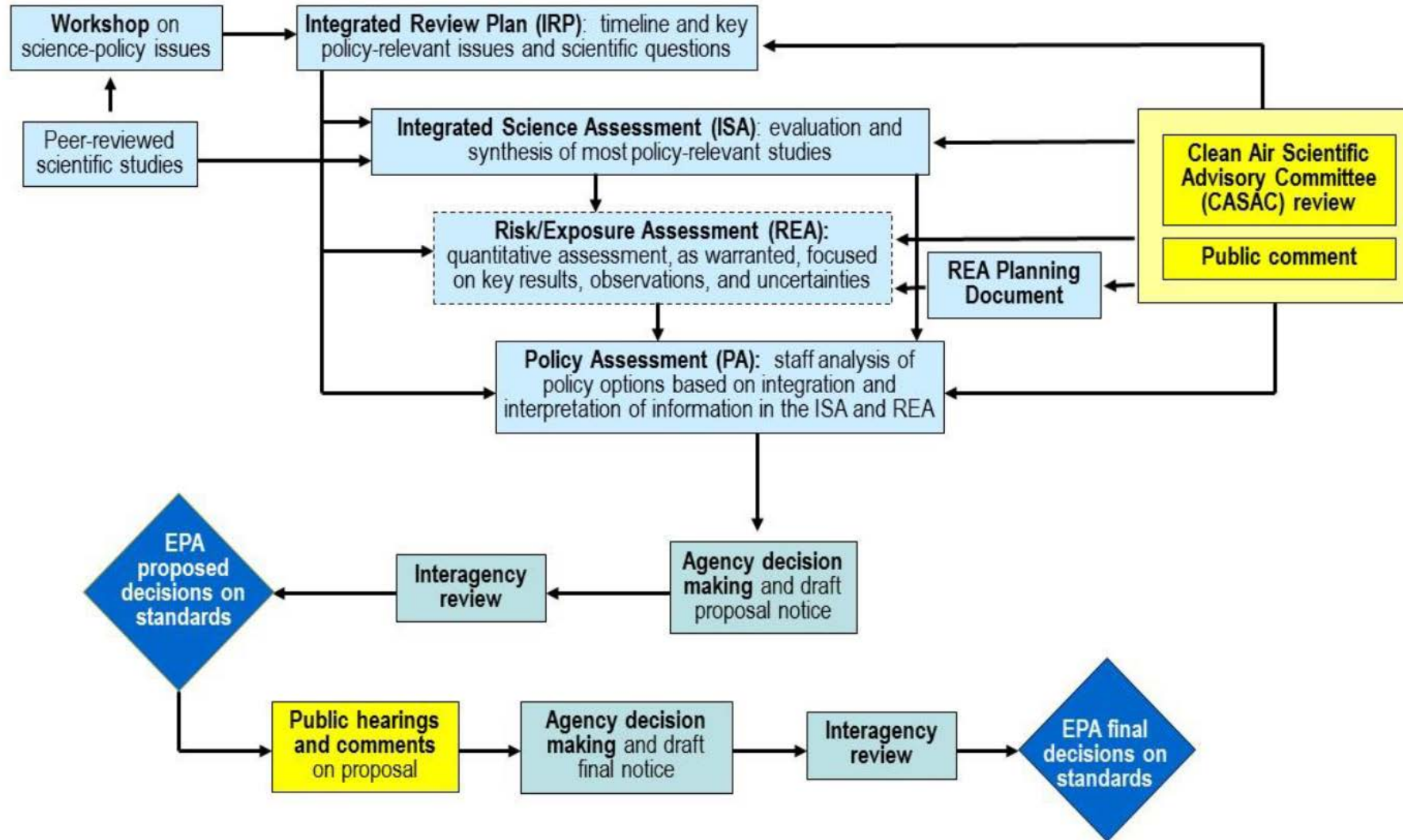
- Members of the Independent Particulate Matter Review Panel.
- Union of Concerned Scientists hosted the October 2019 meetings of the Panel. Special thank you to Dr. Gretchen Goldman.
- Mr. Chris Zarba acted in the role of a designated officer for the panel.
- Mr. John Bachmann and Mr. Steven Silverman provided technical and legal clarifications, respectively.
- This presentation has not been reviewed or approved by anyone. The author is solely responsible for its content.

frey@ncsu.edu

Report of the Independent Particulate Matter
Review Panel is at:

ucsusa.org/pmpanel

Overview of EPA's Process for Reviewing National Ambient Air Quality Standards, 2016



Generic “Full” NAAQS Science Review from CASAC and Public Perspective

CASAC Meeting*	Topic
1 & 2	Draft Integrated Review Plan
3 & 4	1 st Draft Integrated Science Assessment
	Risk & Exposure Assessment Plan
5 & 6	2 nd Draft Integrated Science Assessment
	1 st Draft Risk & Exposure Assessments
7 & 8	2 nd Draft Risk & Exposure Assessments
	1st Draft Policy Assessment
9 & 10	2nd Draft Policy Assessment

*Meetings 1, 2, 4, 6, 8, 10 by teleconference; Meetings 3, 5, 7, 9 face-to-face
Public Comment at EVERY meeting (10 opportunities)

Pruitt/Wheeler (P/W) Particulate Matter NAAQS Science Review from CASAC and Public Perspective

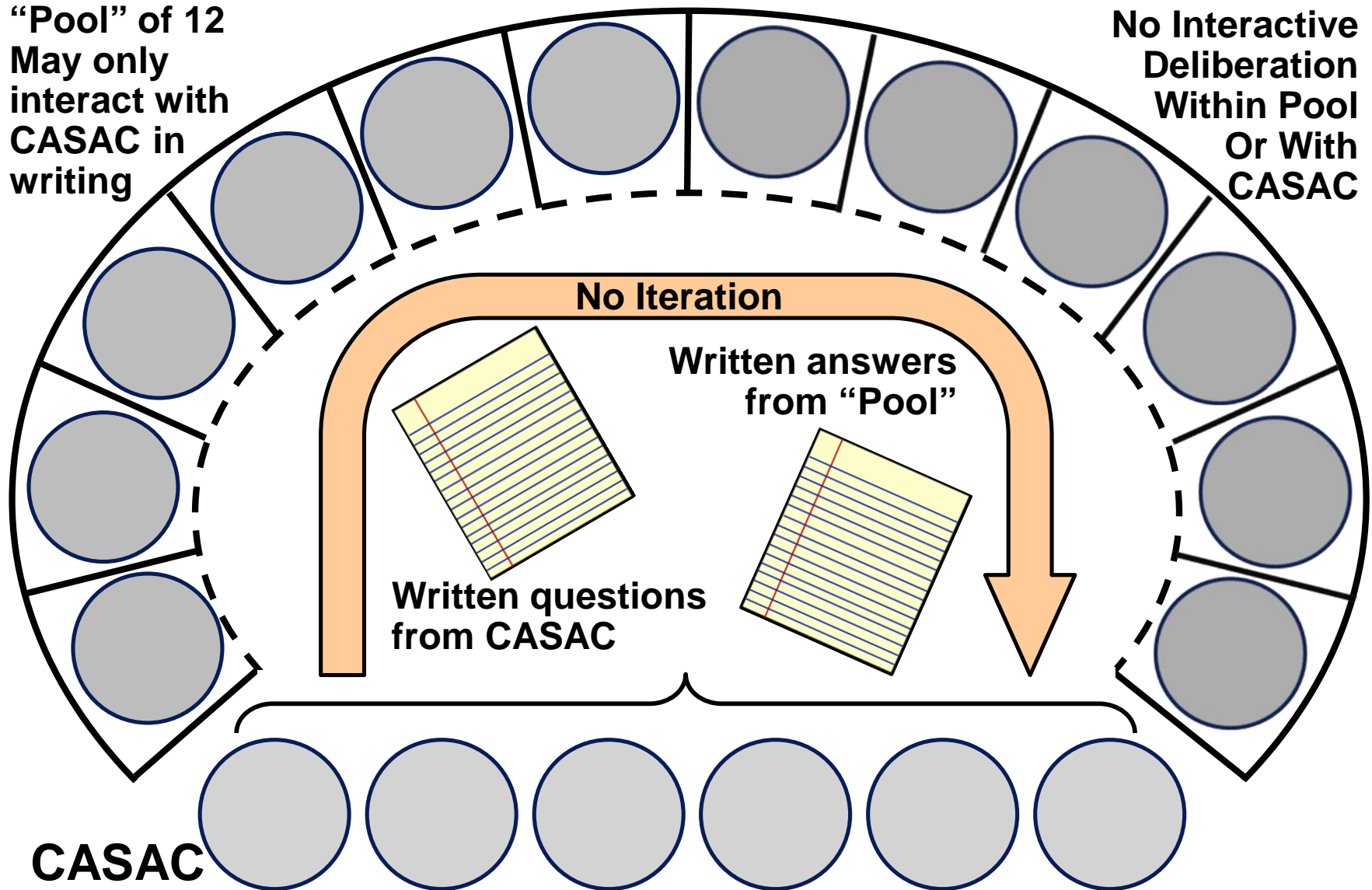
CASAC Meeting*

Topic

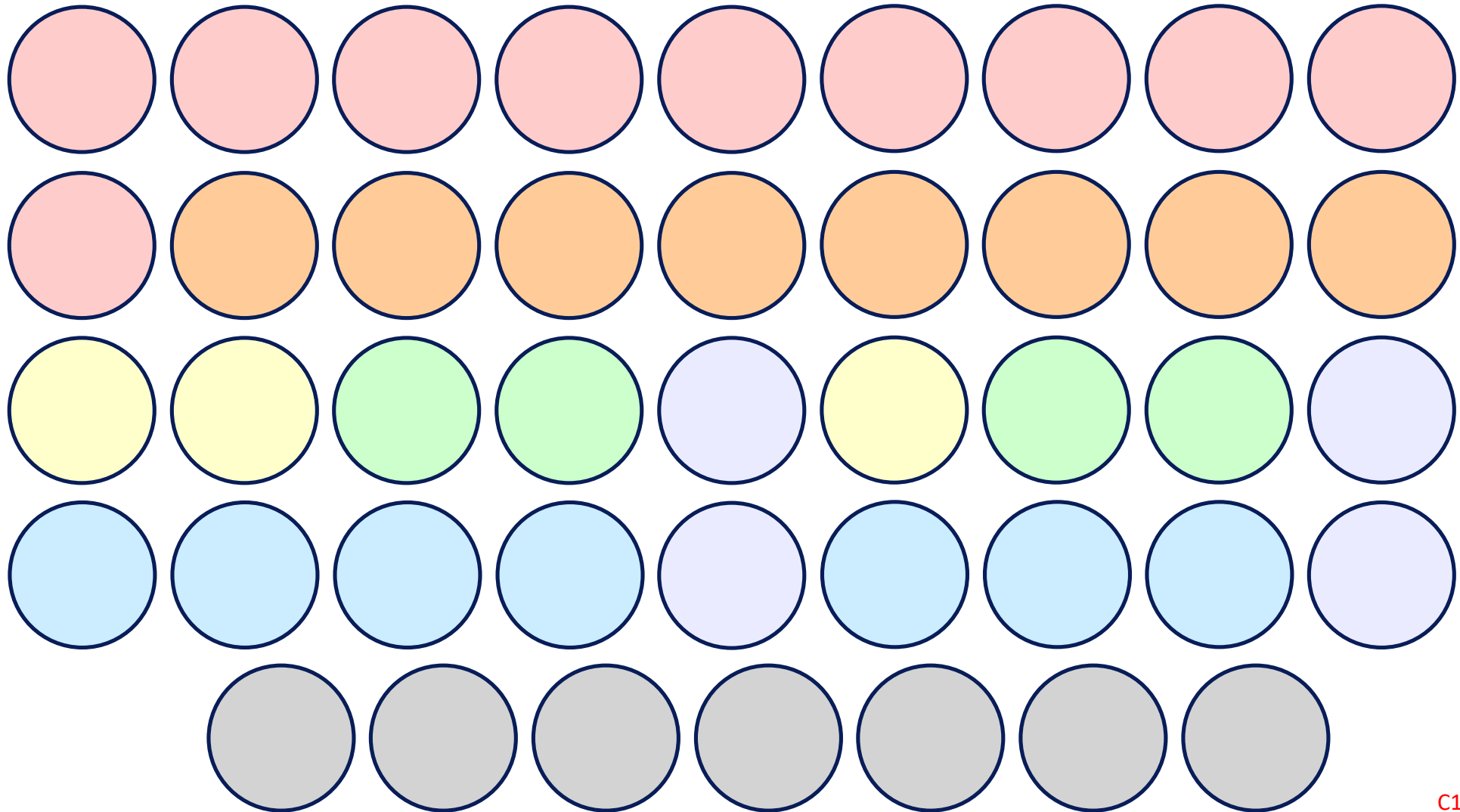
1 & 2	Draft Integrated Review Plan	2016 Before P/W
3 & 4	1 st Draft Integrated Science Assessment	
5 & 6	1st Draft Policy Assessment	

*Meetings 1, 2, 4, 6 by teleconference; Meetings 3, 5 face-to-face
Public Comment at EVERY meeting (6 opportunities) [Only 4 in P/W era]

Wheeler Ad Hoc "Pool" of External Consultants for PM and O₃ Reviews



Typical Pre-Pruitt/Wheeler CASAC for PM and O₃ Reviews: CASAC Augmented with PM and O₃ Panels



Report of the Independent Particulate Matter Review Panel

- ucsusa.org/pmpanel
- 11 page letter (5 pages of text)
- Attachment A: Panel Roster (2 pages)
- Attachment B: Consensus Responses (43 pages)
- Attachment C: Individual Member Comments (117 pages)
- Attachment D: History, Membership Criteria, and Administrative Procedures of the Panel
- Attachment E: Panel Member Biosketches

Major Findings: Coarse PM

- Coarse PM (PM_{10} as an indicator for $PM_{10-2.5}$)
 - Retain current indicator, form, and averaging time (24-hour)
 - Current level of protection should at least be maintained
 - Need to revise downward with downward revision of 24-hour $PM_{2.5}$ standard.
 - Should move to $PM_{10-2.5}$ as the indicator in the next review.

Major Findings: Visibility

- Welfare (Secondary) Standards
 - Current annual standard has no effect ($15 \mu\text{g}/\text{m}^3$ vs. $12 \mu\text{g}/\text{m}^3$ for primary $\text{PM}_{2.5}$ standard.
 - Annual should at least match primary annual.
 - 24-hour standard is not adequate to protect against visibility effects
 - A second draft of the PA should identify and analyze alternatives
 - Panel offers recommendations regarding alternative indicators, averaging times, forms, and levels to be considered.

Process Issues (Overview, Examples)

- Since 2017, the Panel finds that the EPA has made unwarranted changes to the CASAC and the NAAQS review process.
- Detailed recommendations to reverse the unwarranted changes are in the consensus responses.
- A second draft of the ISA should be reviewed by CASAC and the public, and the ISA should be finalized, prior to release of a second external review draft of the PA
- The CASAC PM Review Panel should be reappointed to provide CASAC with the expertise it needs.

New Federal Reference Methods Needed

- The Panel recommends that Federal Reference Methods be developed for Ultrafine Particles and Black Carbon
- FRMs for UFP and BC should be deployed to collect data need for health studies and for baselines

Break



Particulate Matter: Spotlight on Health Protection



Advisory Council Discussion with Health Effects Panel

Discussion Questions

Are current PM standards sufficiently health protective?

Are some species of PM more dangerous than others?

What is role of ultrafine particles (UFPs)?

How should air quality targets be set? Should form of target expand to account for more than just mass?

How should we include draft PM ISA's new "likely-causal" health endpoints (nervous system effects, cancer) and new more sensitive populations (children, lower socio-economic status)?

What are health impacts of high-concentration acute events (e.g., wildfires)? How should we compare them to day-to-day PM impacts?

Lunch

Keynote –
Gina McCarthy



Particulate Matter:
Spotlight on Health Protection



Particulate Matter: Spotlight on Health Protection

Gina McCarthy

- Former EPA Administrator
- Finalized the Clean Power Plan and the Clean Water Rule
- Professor of the Practice of Public Health in the Department of Environmental Health at Harvard T.H. Chan School of Public Health
- Director of the Center for Climate, Health, and the Global Environmental
- Member of the Board of Directors of the Energy Foundation and Ceres
- M.Sc. in Environmental Health Engineering, Planning and Policy from Tuft's University





Particulate Matter: Spotlight on Health Protection



Exposure and Risk



Lauren Zeise, Ph.D.

- Appointed by Gov. Brown as Director of the California Office of Environmental Health Hazard Assessment in December 2016
- Former Chief of the cancer unit at the California Department of Health Services
- Leading role in OEHHA's development of CalEnviroScreen
- Co-led the team that developed the hazard trait regulation for California's Safer Consumer Products program
- Member, fellow, former editor, and former councilor of the Society for Risk Analysis
- 2008 recipient of the Society's Outstanding Risk Practitioner Award
- Ph.D. from Harvard University

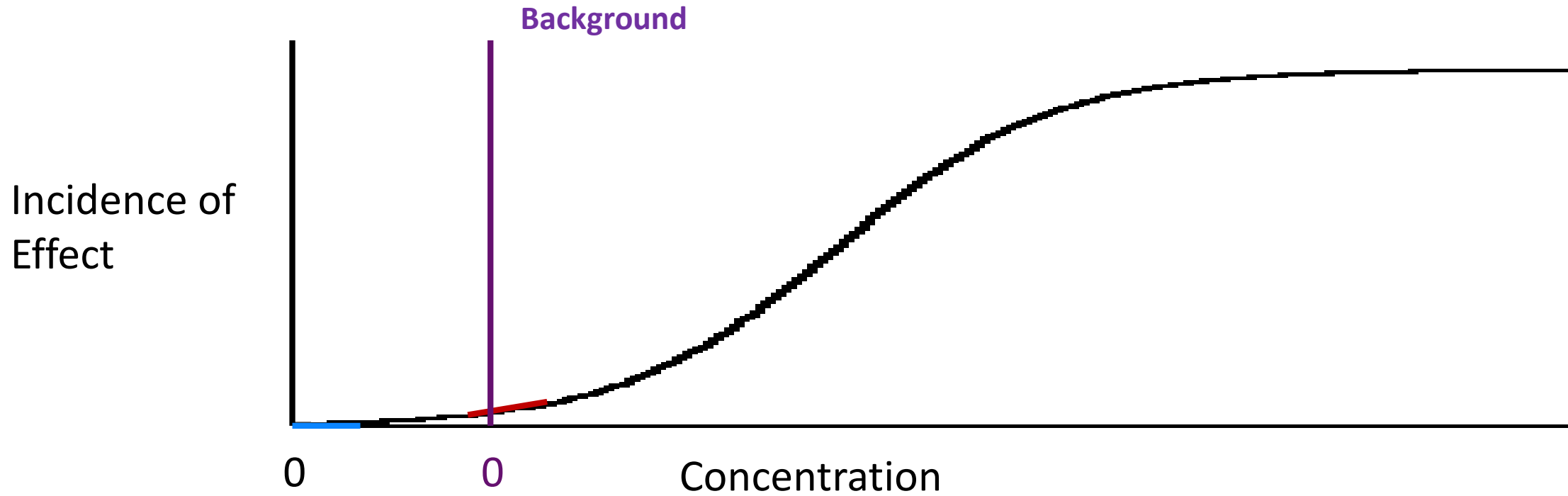
Exposure and Risk Panel
Particulate Matter: Spotlight on Health
Bay Area Air Quality Management District
October 28, 2019

Lauren Zeise

California Environmental Protection Agency
Office of Environmental Health Hazard Assessment



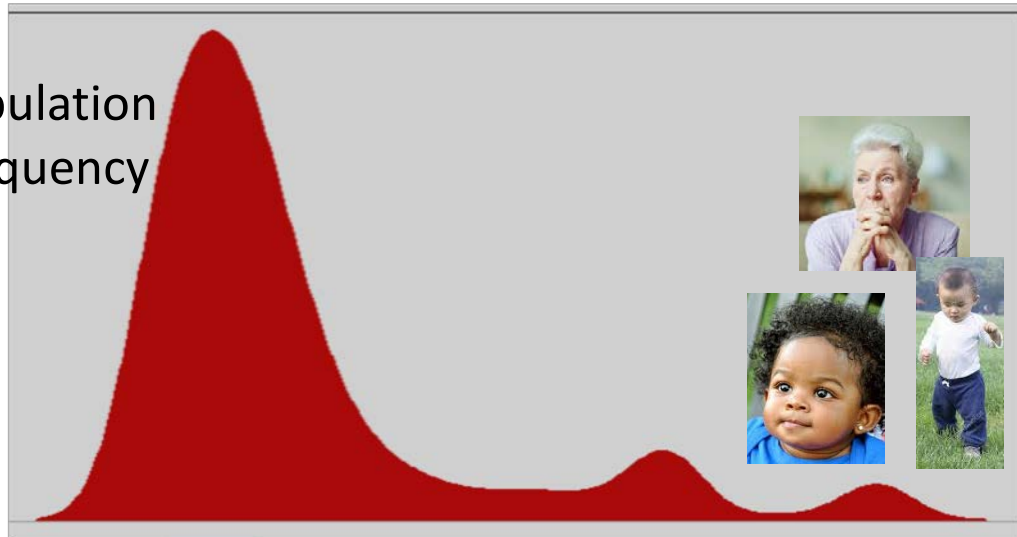
Population Concentration-Response Relationships



Variability Underlying Concentration Response Observations

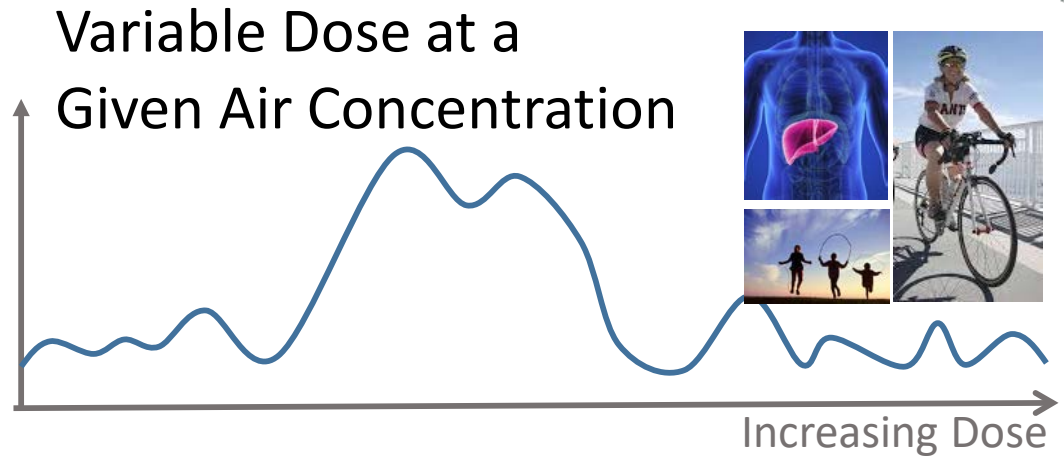
Variable Risk at a Given Dose

Population Frequency

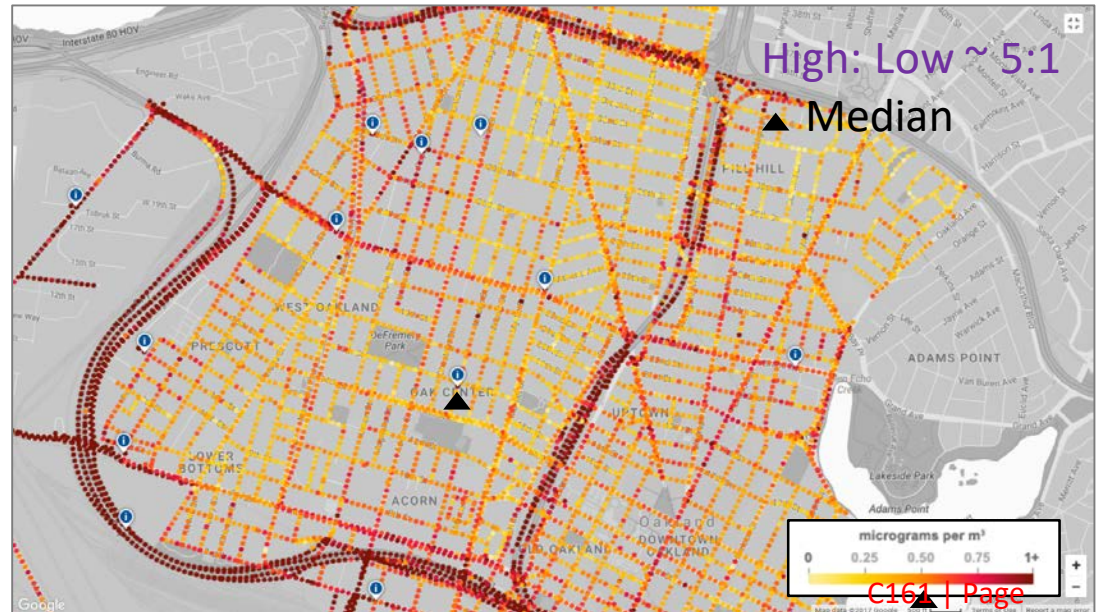


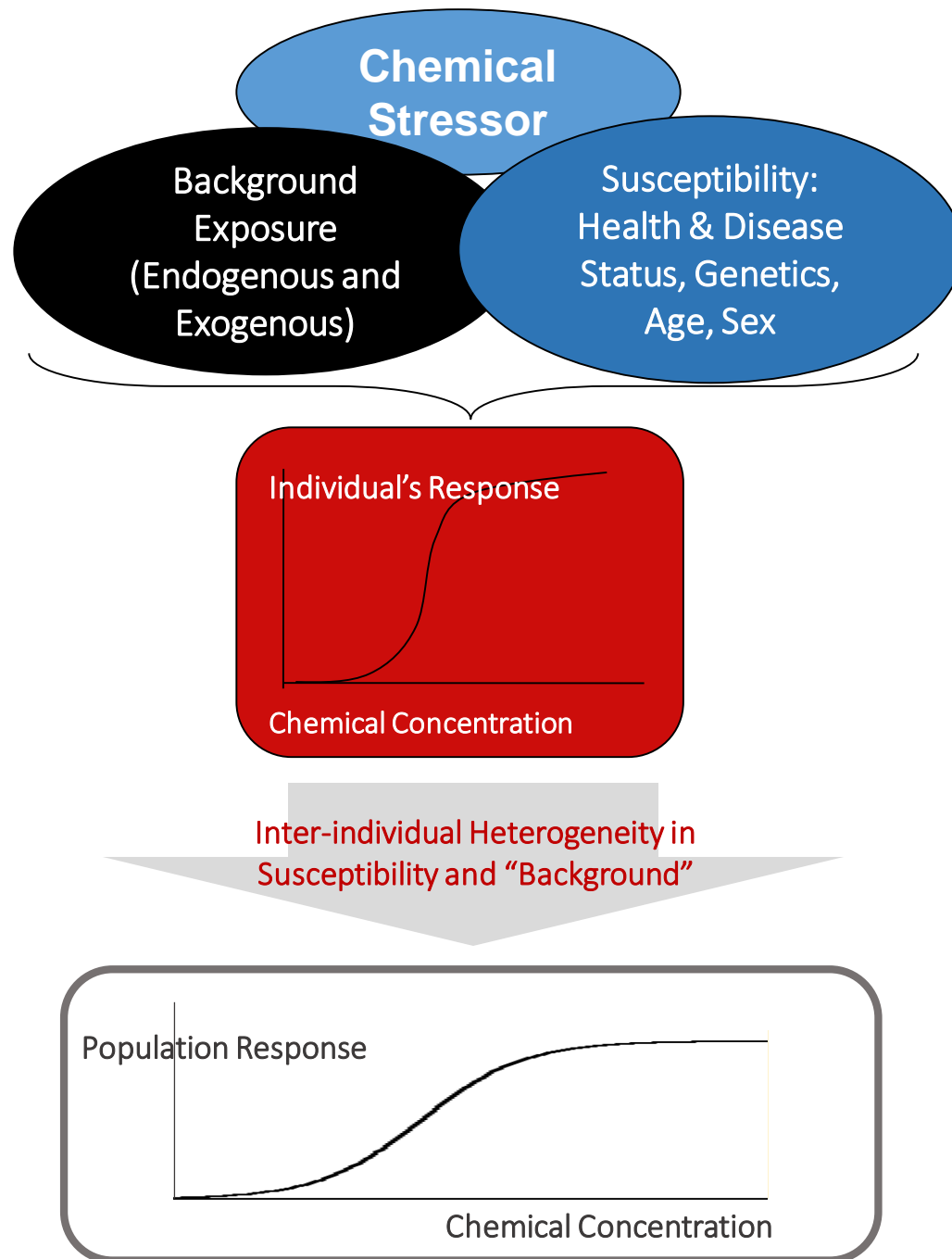
Increasing Risk

Population Frequency



Variable Concentration with Location





Considerations for Interventions

- Risk determined by individual's biologic make-up, health status, endogenous and exogenous exposures that affect toxic chemical process
- Differences among people in these factors affect the shape of the concentration response curve

Individual vs Population Concentration-Response

	Individual level	Population Level
1. An individual's: Nonlinear The population: Linear	<p>Probability of Effect</p> <p>Background Concentration</p>	<p>Fraction of Population Affected</p> <p>Concentration</p>
2. An individual's: Nonlinear The population: Nonlinear	<p>Probability of Effect</p> <p>Background Concentration</p>	<p>Fraction of Population Affected</p> <p>Background Concentration</p>
3. An individual's: Linear The population: Linear	<p>Probability of Effect</p> <p>Concentration</p>	<p>Fraction of Population Affected</p> <p>Concentration</p>

East Bay Diesel Exposure Project



- Measure exposures to diesel exhaust in East Bay community residents
 - Biomonitoring – urine (1-Nitropyrene metabolites)
 - Dust in home
 - Indoor Air (1-Nitropyrene, Black carbon with real-time sensor)
- Measure in child-parent pairs to evaluate exposure patterns within family and across ages
- Collect urine & air samples at two time points to look at seasonal differences
 - 25 families: one urine sample at end of 4 day periods
 - 15 families: daily urine samples x 4 days
- Collect information related to sources and activities
 - Exposure questionnaire
 - GPS data loggers – every 5 minutes
 - Activity diaries



BIOMONITORING
CALIFORNIA



W UNIVERSITY of
WASHINGTON



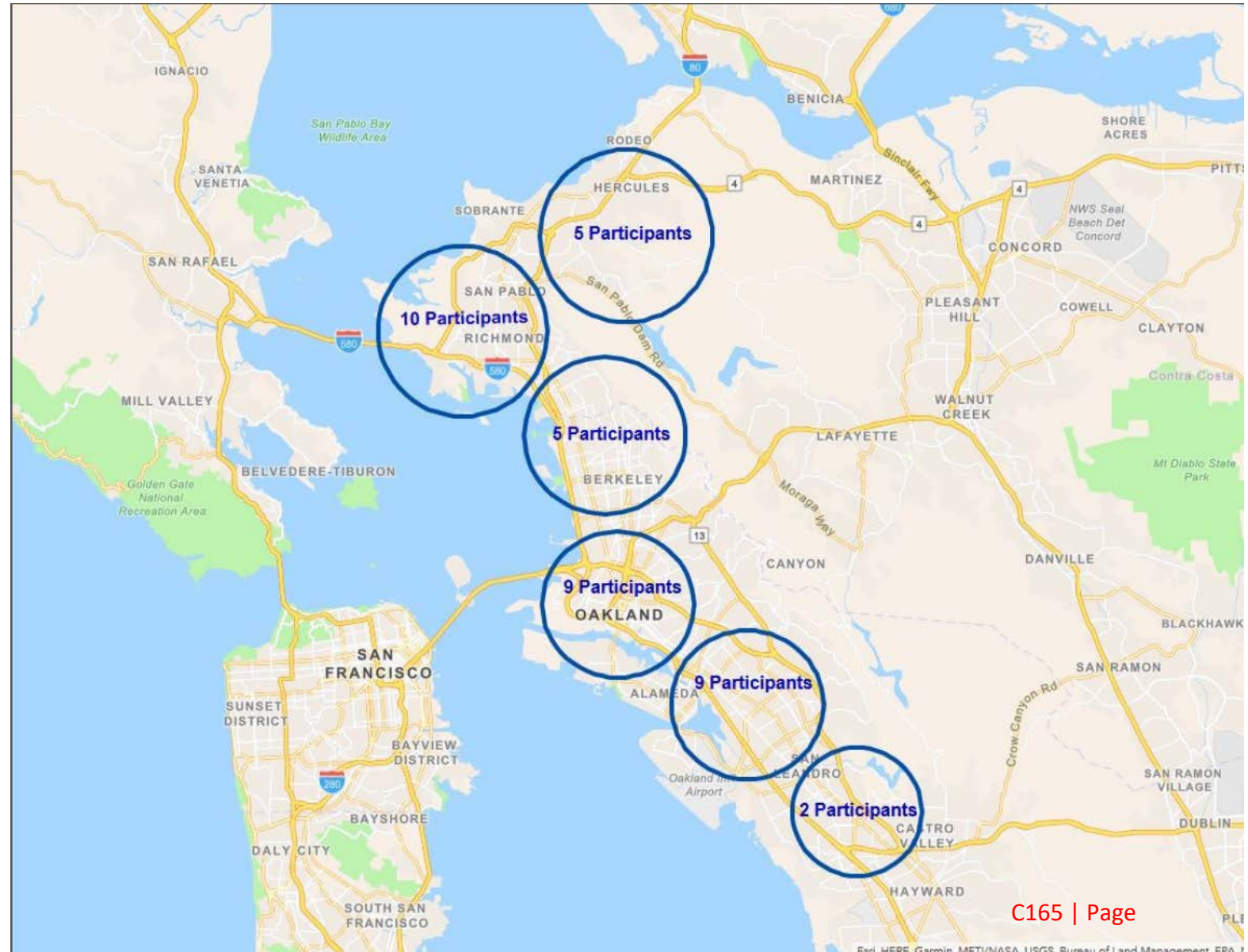
Berkeley
UNIVERSITY OF CALIFORNIA



EBDEP Participant Locations



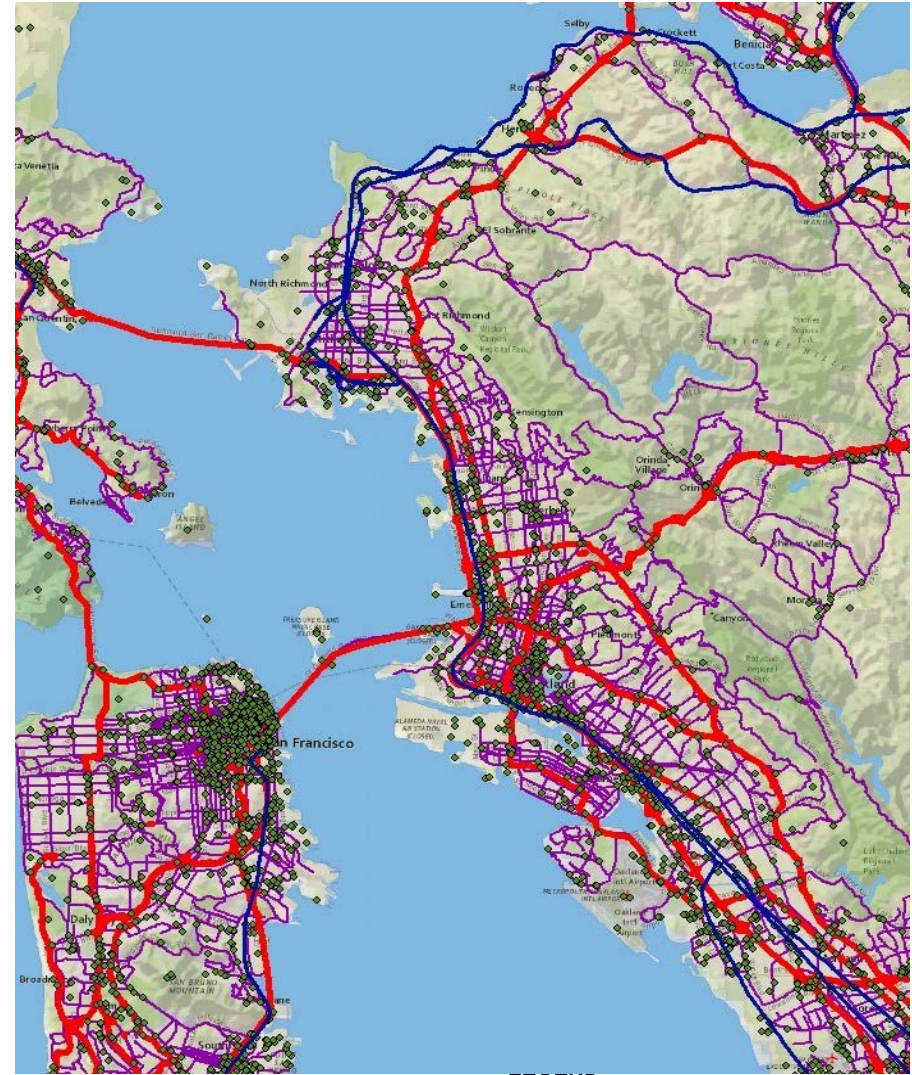
- East Bay
- Neighborhoods with a range of diesel exhaust exposure, based on:
 - CalEnviroScreen's diesel particulate matter indicator (based on CARB data)
 - Diesel truck traffic patterns
 - Local air pollution mapping



GIS Diesel Source Layers and Maps



- Permitted stationary emission sources (BAAQMD)
- Railway lines and railway road crossings
- Caltrans Truck Network
- Caltrans Bottlenecks (highway congestion)
- AC Transit and Amtrak bus routes and stops
- Major roads
- Industrial land use zoning maps (county)
- Highway Performance Monitoring System traffic data
- California ports



— Highway — HPMS road segment — Railway line ◆ BAAQMD permitted emission source

Complementary Pilot Air Quality Study

- Measure ambient air concentrations of black carbon and selected PAHs in areas of Richmond relevant to EBDEP
- Conduct field sampling for several days during periods of moderate and high pollution
- Analyze results to:
 - Compare levels across location and time
 - Examine patterns for possible clues on sources



Principal Investigator: Betsey Noth, UC Berkeley

OEHHA funded

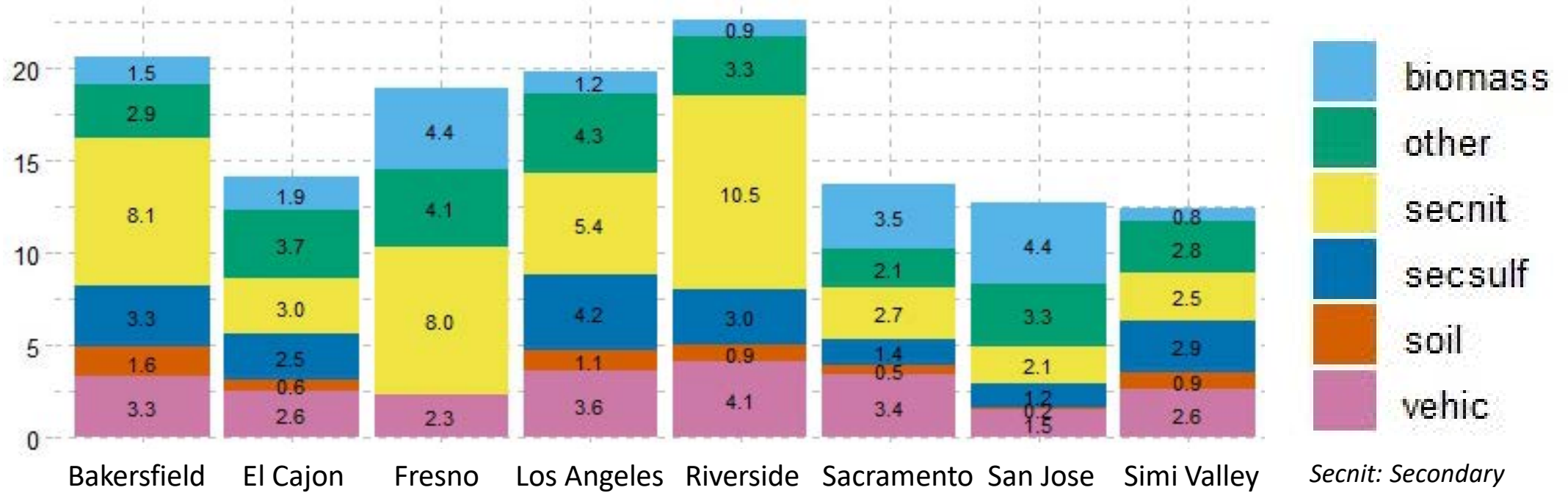


OEHHA Biomonitoring to Support AB 617

- Directly measure exposure to a chemical(s) of concern
- Establish baseline exposures prior to reduction efforts
- Examine exposures associated with a specific source(s) in the community, and/or
- Evaluate the effectiveness of exposure reduction efforts

Estimated PM_{2.5} Source Contribution by Monitoring Site

Annual Average PM_{2.5} $\mu\text{g}/\text{m}^3$



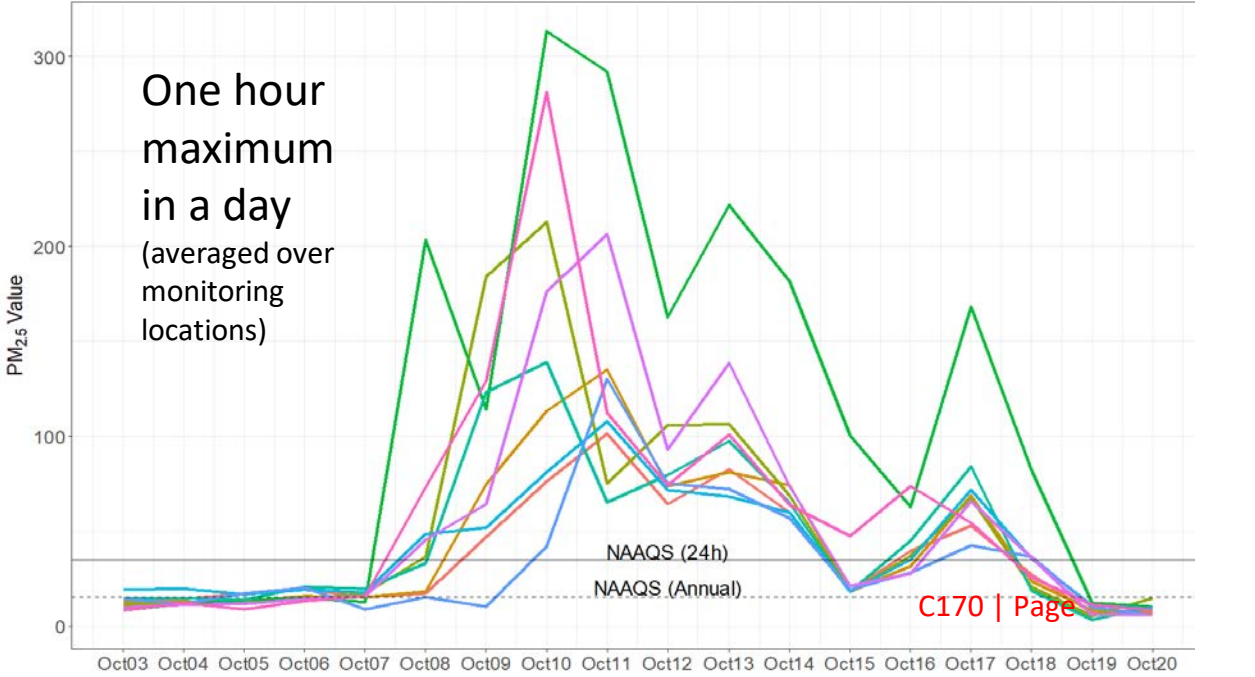
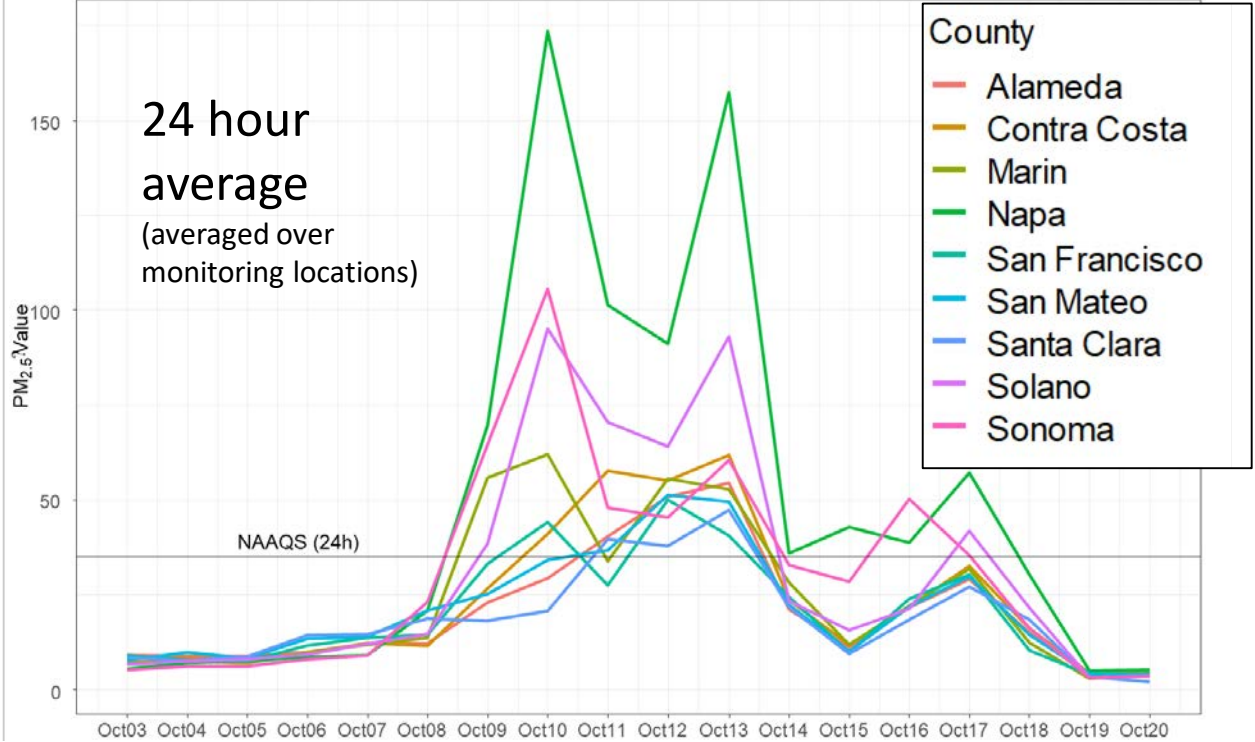
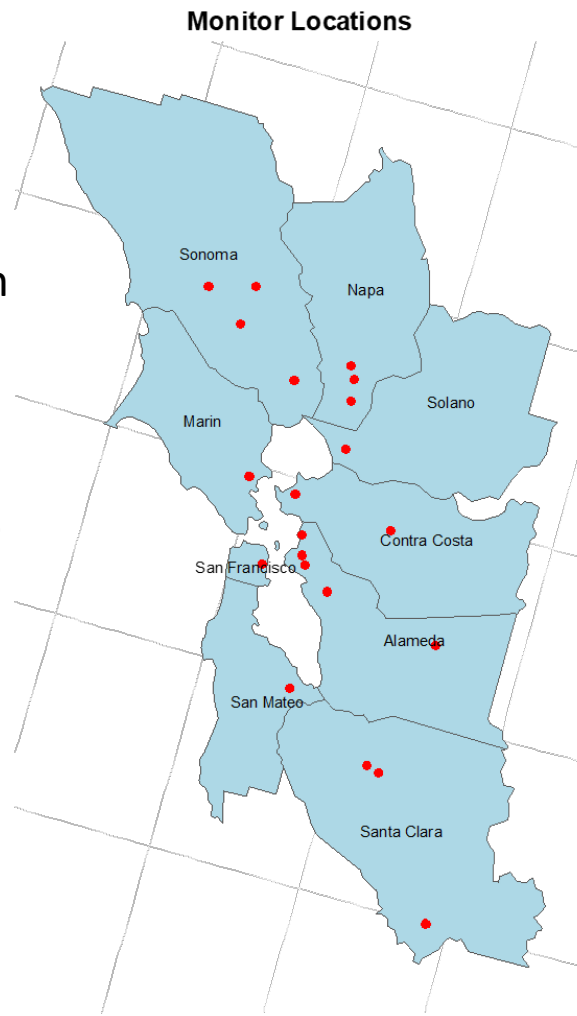
Secnit: Secondary Ammonium Nitrate
Secsulf: Secondary Ammonium Sulfate

Source	Marker Constituents
Biomass	EC, OC, K
Secondary Ammonium Nitrate	NO_3^- , NH_4^+
Secondary Ammonium Sulfate	SO_4^{2-} , NH_4^+
Resuspended Soil	Al, Si, Ca, Fe, Ti
Vehicular Emissions	EC, OC, Fe, Cu, Zn

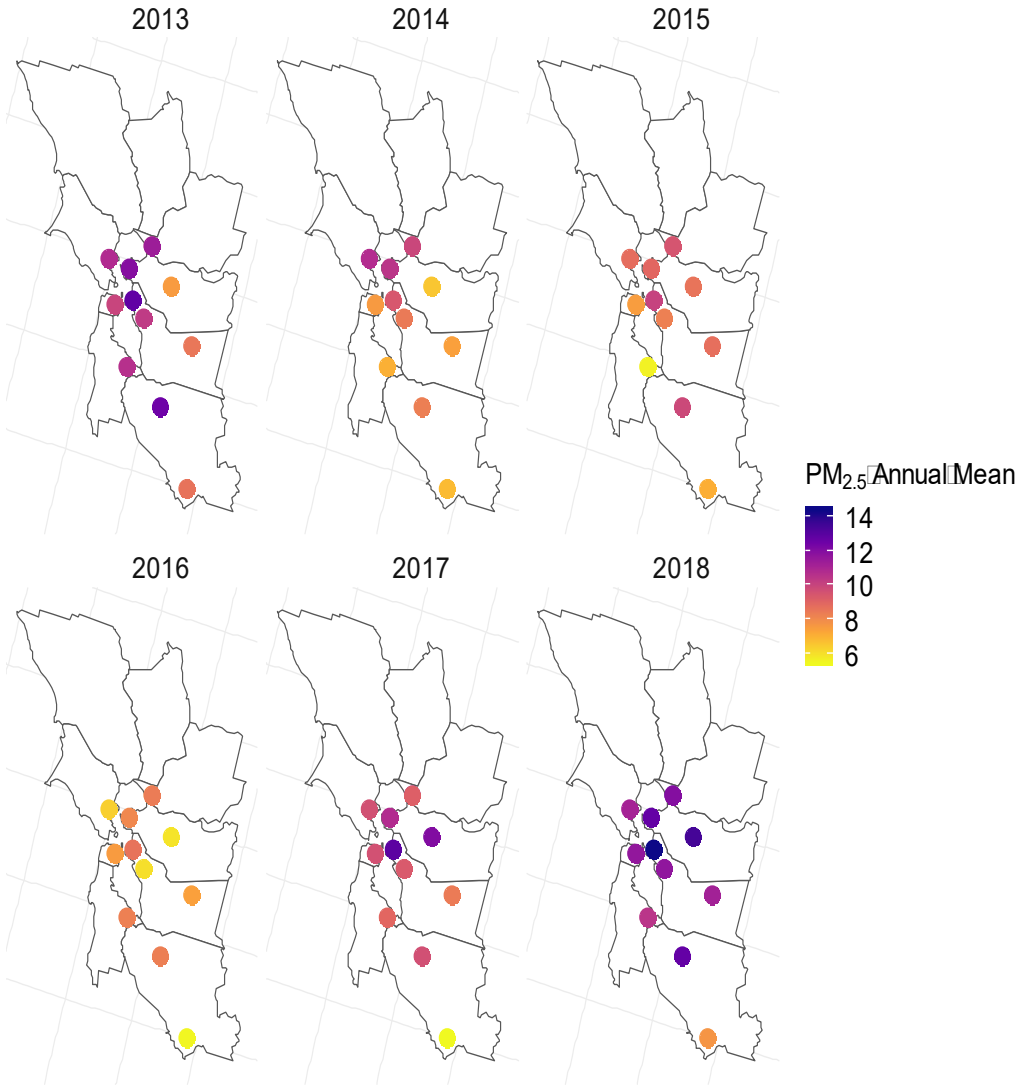
PM_{2.5} in Bay Area During 2017 Napa Wildfire

Health Outcomes Being Investigated

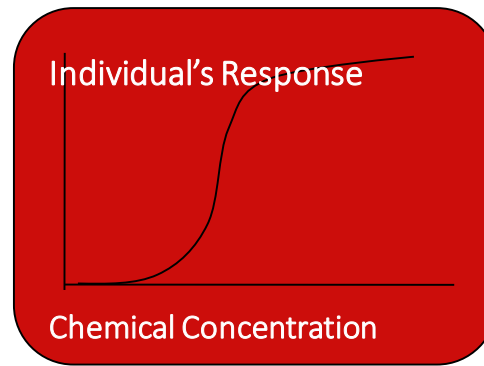
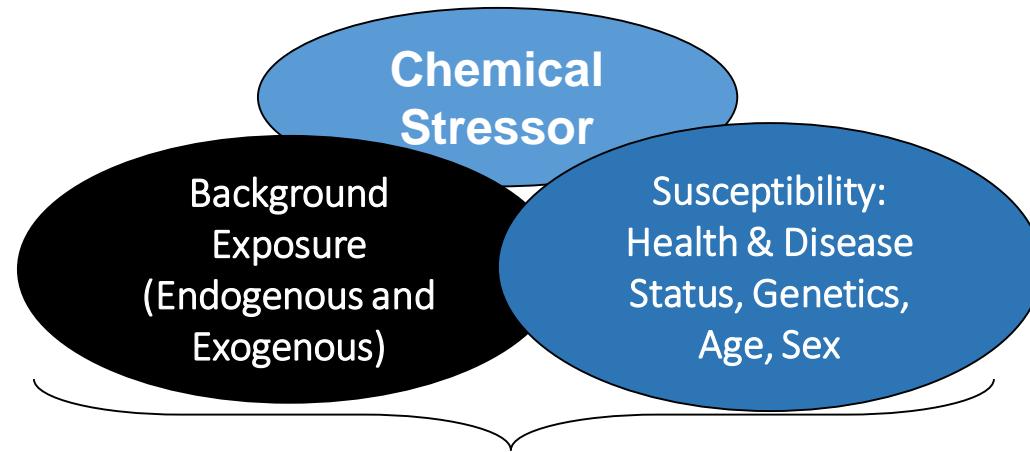
- Cardiovascular Disease
- Ischemic Heart Disease
- Acute Myocardial Infarction
- Dysrhythmia
- Cerebrovascular Disease
- Transient Ischemic Attack
- Peripheral Vascular Disease
- Diabetes
- Respiratory Disease
- Asthma/Wheeze
- Pneumonia
- Chronic Lower Respiratory Disease
- Acute Upper Respiratory Infection
- Mental/Behavioral Disorders



Wildfire Affects Annual Average of PM_{2.5}

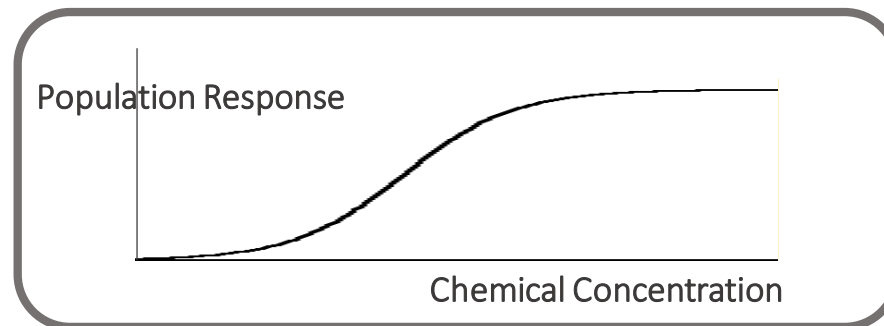


- Wildfire PM adds to underlying “baseline”
- Monitor in West Oakland:
 - 2017: 12.9 μg/m³
 - 2018: 14.4 μg/m³



Inter-individual Heterogeneity in Susceptibility and "Background"

A large, light gray downward-pointing arrow with the text 'Inter-individual Heterogeneity in Susceptibility and "Background"' centered inside it.



Acknowledgements

- OEHHA Community Health and Environmental Impacts Section: Rupa Basu, Keita Ebisu, et al.
- OEHHA Safer Alternatives Assessment and Biomonitoring Section: Sara Hoover, Russ Bartlett, Duyen Kauffman et al.



Particulate Matter: Spotlight on Health Protection



Julian Marshall, Ph.D.

- Kiely Endowed Professor of Environmental Engineering at University of Washington with a focus on air quality management
- Founded and runs the Grand Challenges Impact Lab, a UW study abroad program in Bangalore, India
- Associate Editor for Environmental Health Perspectives and Development Engineering
- Published over 100 peer-reviewed journal articles
- Ph.D. in Energy and Resources from UC Berkeley



Particulate Matter: Spotlight on Health Protection



Scott Jenkins, Ph.D.

- Senior Environmental Health Scientist in EPA's Office of Air Quality Planning and Standards (OAQPS)
- Currently leading EPA's review of the National Ambient Air Quality Standards (NAAQS) for Particulate Matter (PM)
- Howard Hughes Postdoctoral Research Fellow in the Department of Cell Biology at Duke University
- Ph.D. in Behavioral Neuroscience from the University of Alabama at Birmingham

REVIEW OF THE NATIONAL AMBIENT AIR QUALITY STANDARDS FOR PARTICULATE MATTER

OVERVIEW OF THE DRAFT POLICY ASSESSMENT

Scott Jenkins

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards

Presentation to the Bay Area Air Quality Management
District

October 28, 2019

Outline of Presentation

- Overview of the standards, process and schedule
- Key information and analyses in draft Policy Assessment
- Preliminary conclusions on the primary PM_{2.5} standards

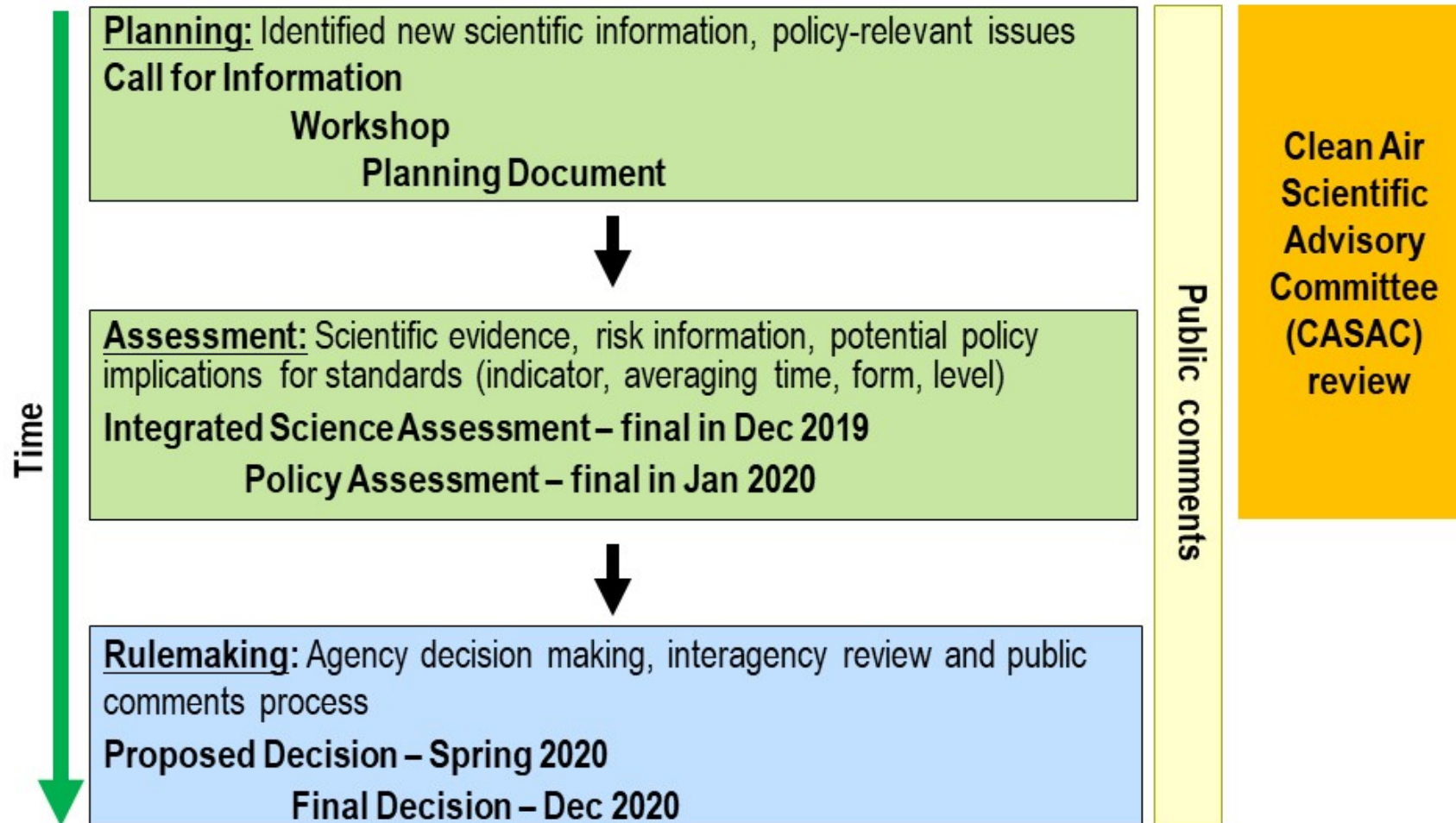
Current PM Standards Under Review

Current Standards – Last Review Completed in 2012*					Decisions in 2012 Review
Indicator	Averaging Time	Primary/Secondary	Level	Form	
PM _{2.5}	Annual	Primary	12.0 µg/m ³	Annual arithmetic mean, averaged over 3 years	Revised level from 15 to 12 µg/m ³ **
		Secondary	15.0 µg/m ³		Retained**
	24-hour	Primary and Secondary	35 µg/m ³	98th percentile, averaged over 3 years	Retained
PM ₁₀	24-hour	Primary and Secondary	150 µg/m ³	Not to be exceeded more than once per year on average over a 3-year period	Retained

*Prior to 2012, PM NAAQS were reviewed and revised several times – established in 1971 (total suspended particulate – TSP) and revised in 1987 (set PM₁₀), 1997 (set PM_{2.5}), 2006 (revised PM_{2.5}, PM₁₀)

**EPA eliminated spatial averaging for the annual standards

Process and Anticipated Schedule for This Review of the PM NAAQS

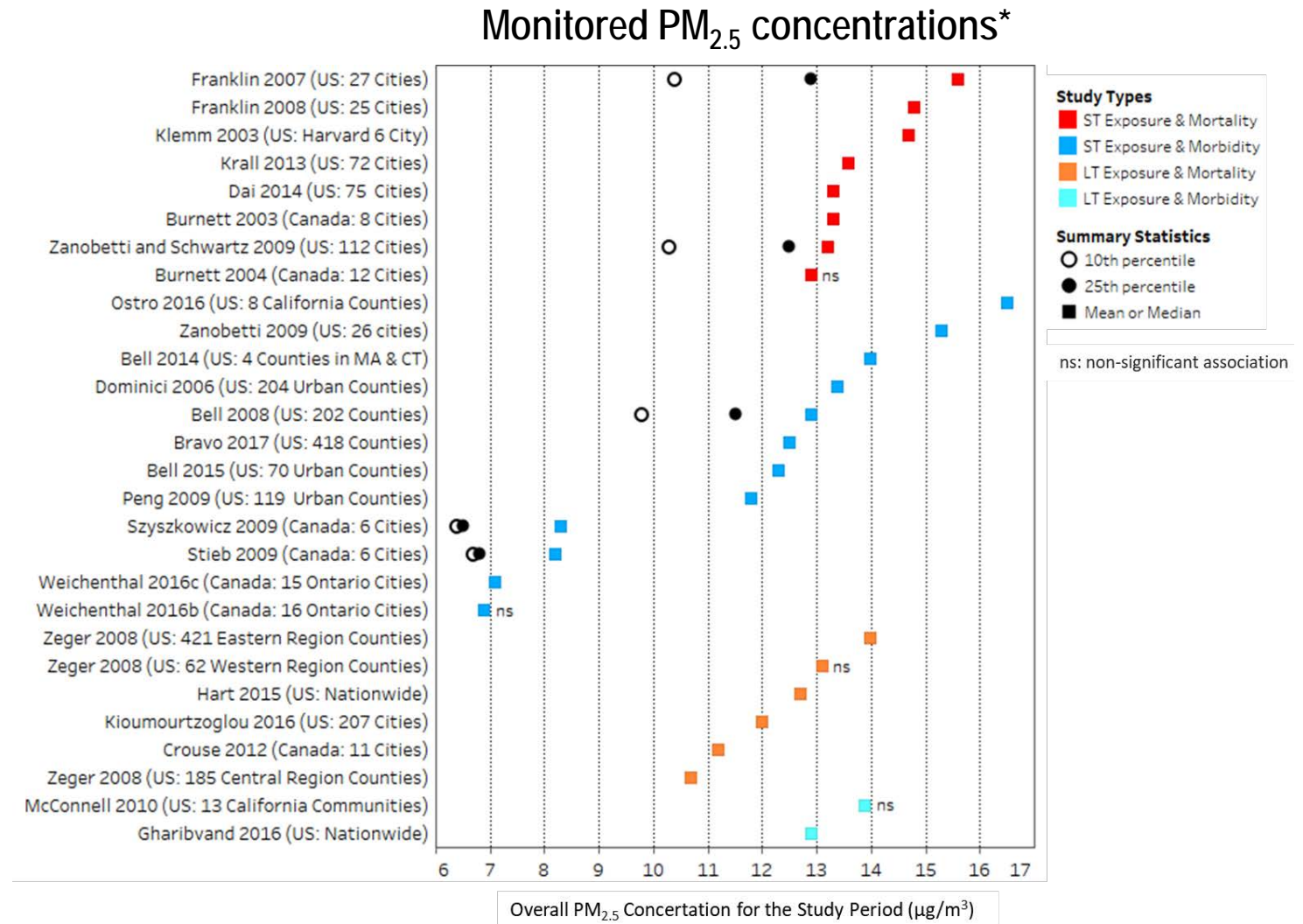


Evaluating Primary PM_{2.5} Standards: Summary of Approach

- The annual PM_{2.5} standard is viewed as the principle means of providing public health protection against the bulk of the distribution of short- and long-term PM_{2.5} exposures
- In previous reviews, conclusions on the annual PM_{2.5} standard have been informed by consideration of the PM_{2.5} air quality distributions associated with mortality or morbidity in epidemiologic studies
 - The current level of 12.0 µg/m³ was set below the overall means of the long- and short-term PM_{2.5} exposure estimates in key studies
- In this review, the draft PA characterizes those distributions by identifying overall means of PM_{2.5} exposure estimates, concentrations corresponding to the lower quartiles of data (when available), and study-area metrics similar to design values (pseudo-design values)
- The 24-hour PM_{2.5} standard, with its 98th percentile form, is viewed as a means of providing protection against short-term exposures to peak PM_{2.5} concentrations, such as can occur in areas with strong contributions from local or seasonal sources, even when mean PM_{2.5} concentrations remain relatively low
- Controlled human exposure studies provide evidence for health effects following single, short-term PM_{2.5} exposures to concentrations that typically correspond to upper end of the PM_{2.5} air quality distribution in the U.S. (i.e., “peak” concentrations – see additional slides)

PM_{2.5} Concentrations in Epidemiologic Studies

- Overall mean concentrations reflect study averages of daily or annual PM_{2.5} exposures – bulk of data generally occurs around overall means
- Key studies consistently reporting positive and statistically significant associations have overall mean PM_{2.5} concentrations > 8.0 µg/m³
- In studies with data available, 75% of health events occurred in areas with mean PM_{2.5} concentrations ≥ 11.5 µg/m³ (U.S. studies) or 6.5 µg/m³ (Canadian studies)

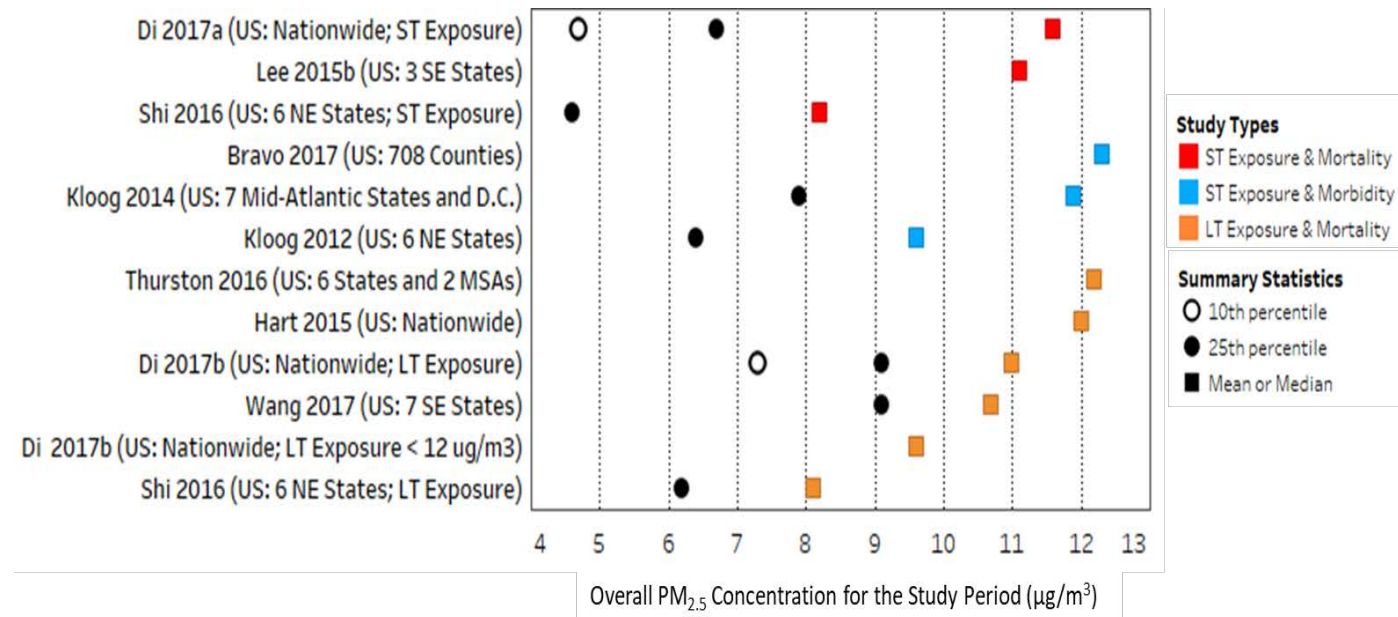


*Colored squares reflect overall study-reported mean (or median) PM_{2.5} concentrations. Circles reflect the mean PM_{2.5} concentrations corresponding to the 25th (filled) and 10th (open) percentiles of health events.

PM_{2.5} Concentrations in Epidemiologic Studies (Continued)

- Many new studies have used hybrid modeling approaches to estimate PM_{2.5} exposures in monitored and unmonitored locations
- Approaches use information from multiple sources, potentially including satellites and models, in addition to ground-based monitors
- All of these key studies report positive and statistically significant associations and have overall mean PM_{2.5} concentrations > 8.0 µg/m³
- In most studies with data available, 75% of exposures (or deaths) are at predicted ambient PM_{2.5} concentrations > 6.0 µg/m³

Hybrid Model-Predicted PM_{2.5} Concentrations



Uncertainties in using this information to inform conclusions on standards include:

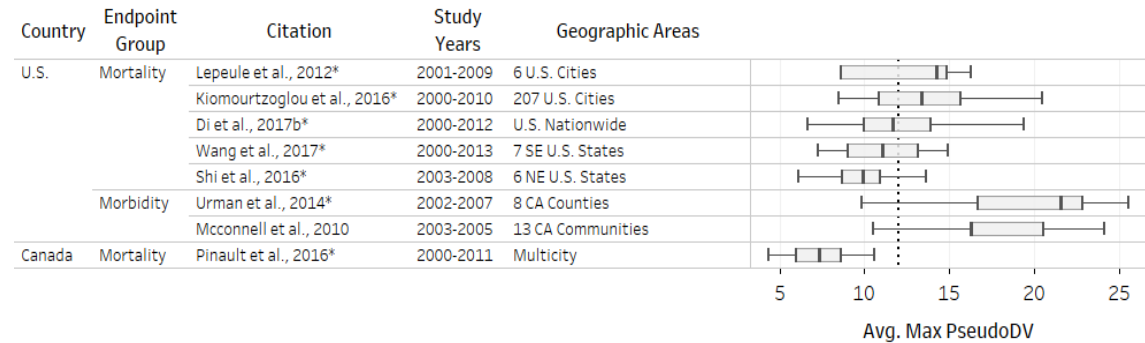
- Mean and lower quartile concentrations are not the same as those used by the EPA to compare with standard levels
- Studies have not identified a threshold concentration below which associations do not occur
- Hybrid model performance varies by location, with factors contributing to poorer performance (e.g., sparse monitoring) often coinciding with relatively low ambient PM_{2.5} concentrations

*Colored squares reflect overall study-reported mean PM_{2.5} concentrations. Circles reflect the mean PM_{2.5} concentrations corresponding to the 25th (filled) and 10th (open) percentiles of exposures or deaths.

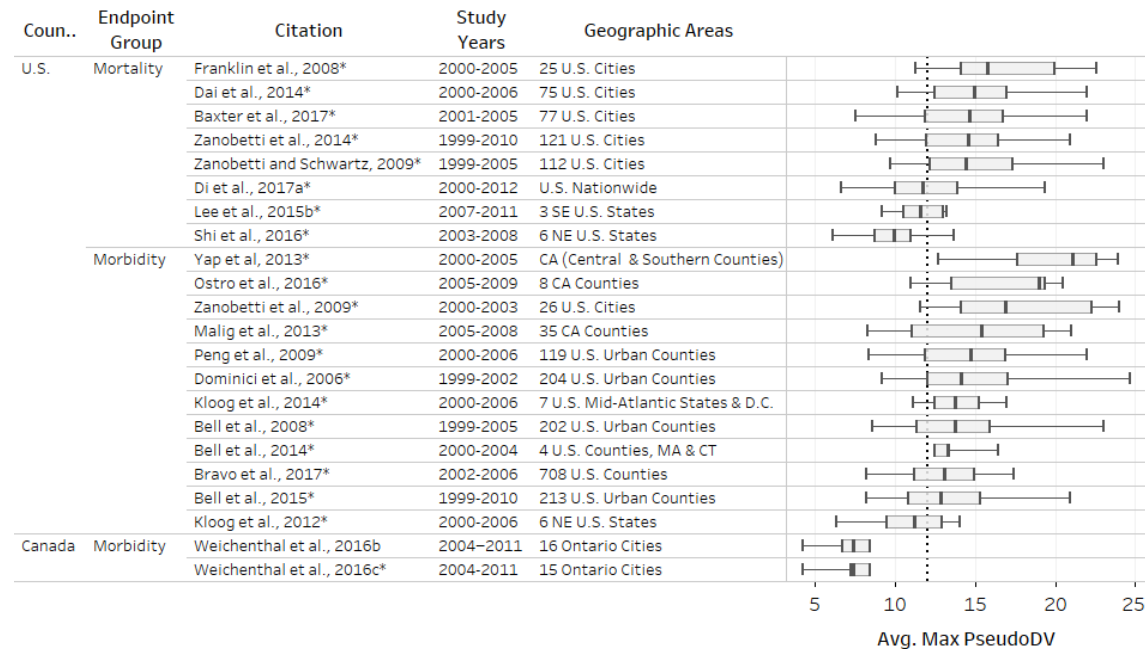
PM_{2.5} Annual Pseudo-Design Values in Locations of Key Studies

- The draft PA also identifies monitor-based metrics – similar to design values – in study locations (annual and 24-hr pseudo-design values)
- For most of the 29 key studies evaluated, ≥ about 25% of study area health events/populations were in locations that generally would have met both standards during study periods
- For 9 key studies, > 50% of study area health events/populations were in such locations
- For 4 key studies, > 75% of study area health events/populations were in such locations
- Uncertainties include:
 - Many studies examine a mix of locations and time periods meeting and violating standards
 - Values are not available in unmonitored areas
 - Values do not reflect current near-road monitoring requirements

Long-term exposure studies

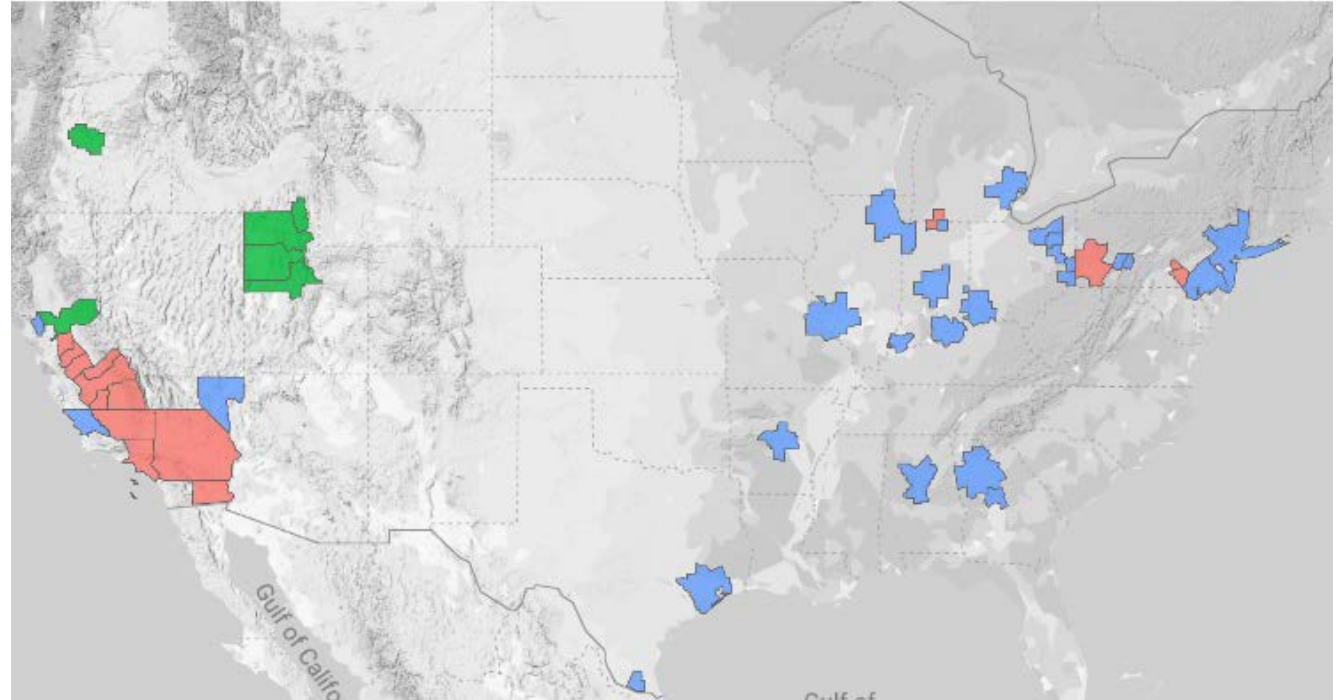


Short-term exposure studies



PM_{2.5} Risk Assessment

- Examined PM_{2.5}-associated mortality risk in 47 urban study areas
- Assessed current standards; alternative annual standards with levels of 11.0, 10.0, and 9.0 µg/m³; alternative 24-hour standard with a level of 30 µg/m³
- 2015 analysis year
- Examined two approaches to adjusting air quality
 - Focus on primary PM
 - Focus on secondary PM



47 urban study areas (population ≥ 30 years: ~60M)

- 30 annual-controlling (population ≥ 30 years: ~50M)
- 11 daily-controlling (population ≥ 30 years: ~4M)
- 6 mixed (population ≥ 30 years: ~5M)

- Above 10 annual and 30 daily
- Above 30 daily
- Above 10 annual

Summary of Risk Estimates

Estimates of PM_{2.5}-associated deaths in the full set of 47 study areas

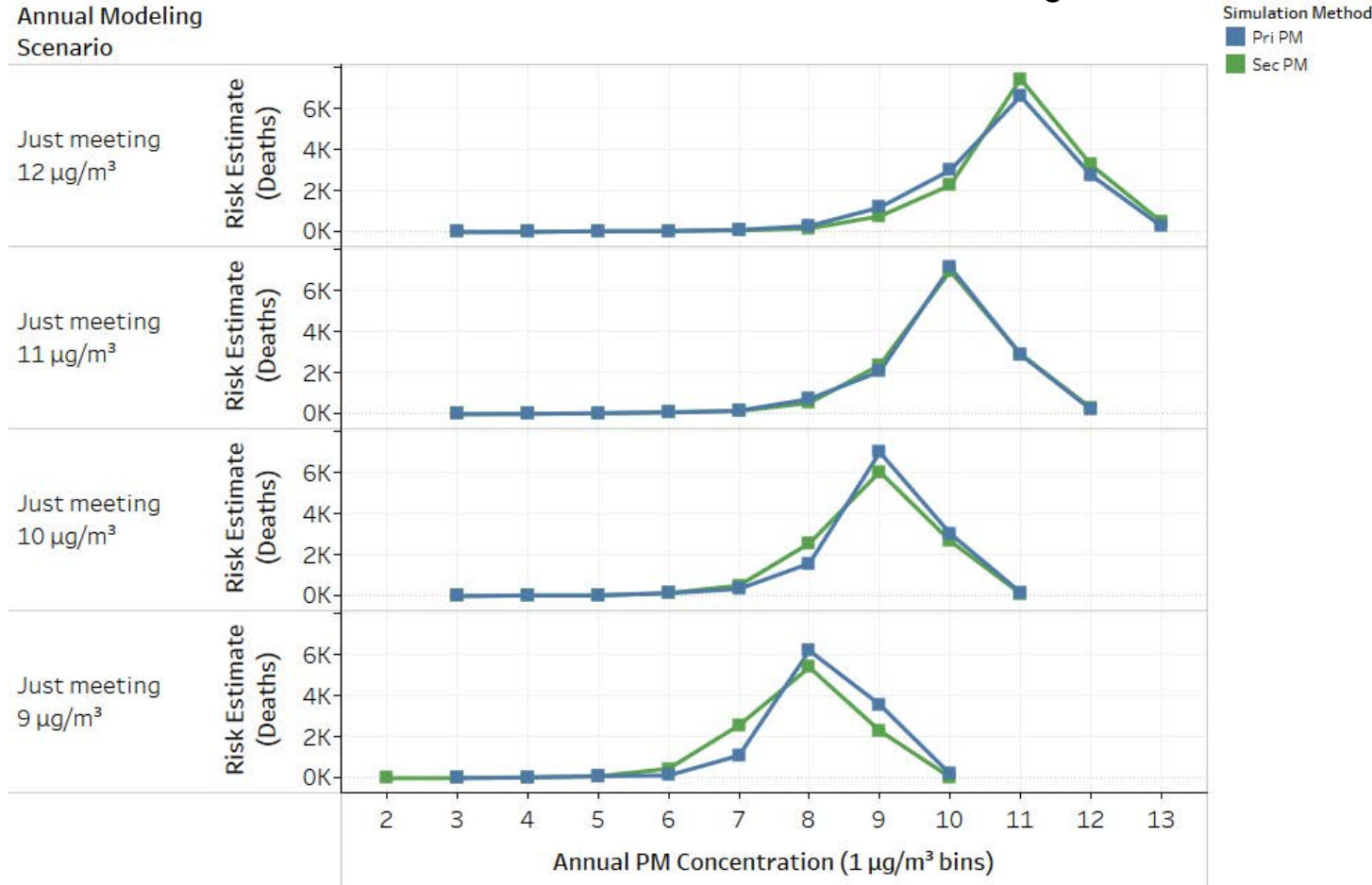
Endpoint	Study	Air quality simulation approach*	Current Standard Absolute Risk (12/35 µg/m ³)	CS (12/35) % of baseline**	Alternative Standard Absolute Risk	
					Alternative Annual (10 µg/m ³)	Alternative 24-hr (30 µg/m ³)
Long-term exposure related mortality						
Ischemic Heart Disease	Jerrett 2016	Pri-PM	16,500 (12,600-20,300)	14.1	14,400 (11,000-17,700)	16,400 (12,500-20,000)
		Sec-PM	16,800 (12,800-20,500)	14.3	14,200 (10,900-17,500)	16,500 (12,600-20,200)
	Pope 2015	Pri-PM	15,600 (11,600-19,400)	13.3	13,600 (10,100-17,000)	15,400 (11,500-19,200)
		Sec-PM	15,800 (11,800-19,600)	13.4	13,400 (9,970-16,700)	15,600 (11,600-19,400)
All-cause	Di 2017	Pri-PM	46,200 (45,000-47,500)	8.4	40,300 (39,200-41,400)	45,700 (44,500-47,000)
		Sec-PM	46,900 (45,600-48,200)	8.5	39,700 (38,600-40,800)	46,200 (44,900-47,500)
	Pope 2015	Pri-PM	51,300 (41,000-61,400)	7.1	44,700 (35,700-53,500)	50,700 (40,500-60,700)
		Sec-PM	52,100 (41,600-62,300)	7.2	44,000 (35,100-52,700)	51,300 (41,000-61,400)
	Thurston 2015	Pri-PM	13,500 (2,360-24,200)	3.2	11,700 (2,050-21,100)	13,300 (2,330-24,000)
		Sec-PM	13,700 (2,400-24,600)	3.2	11,500 (2,010-20,700)	13,500 (2,360-24,200)
Lung cancer	Turner 2016	Pri-PM	3,890 (1,240-6,360)	8.9	3,390 (1,080-5,560)	3,850 (1,230-6,300)
		Sec-PM	3,950 (1,260-6,460)	9.1	3,330 (1,060-5,470)	3,890 (1,240-6,370)
Short-term exposure related mortality						
All cause	Baxter 2017	Pri-PM	2,490 (983-4,000)	0.4	2,160 (850-3,460)	2,460 (970-3,950)
		Sec-PM	2,530 (998-4,060)	0.4	2,120 (837-3,400)	2,490 (982-3,990)
	Ito 2013	Pri-PM	1,180 (-16-2,370)	0.2	1,020 (-14-2,050)	1,160 (-16-2,340)
		Sec-PM	1,200 (-16-2,400)	0.2	1,000 (-14-2,020)	1,180 (-16-2,370)
	Zanobetti 2014	Pri-PM	3,810 (2,530-5,080)	0.7	3,300 (2,190-4,400)	3,760 (2,500-5,020)
		Sec-PM	3,870 (2,570-5,160)	0.7	3,250 (2,160-4,330)	3,810 (2,530-5,070)

* Pri-PM (primary PM-based modeling approach), Sec-PM (secondary PM-based modeling approach)

** CS denotes the current standard.

Summary of Risk Estimates (Continued)

Distributions of estimated risks in the 30 study areas where the annual standard is controlling*



Uncertainty in risk estimates results from uncertainties in the underlying epidemiologic studies, in the air quality adjustments, and in the application of study and air quality information to develop quantitative estimates of PM_{2.5}-associated mortality risks

*Estimates of ischemic heart disease deaths associated with long-term PM_{2.5} exposures for air quality adjusted to simulate “just meeting” the current and alternative primary standards (based on Jerrett et al., 2016)

Preliminary Conclusions on the Current Primary PM_{2.5} Standards

- 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
- Basis for this preliminary conclusion:
 - Long-standing body of health evidence, strengthened in this review, supporting relationships between PM_{2.5} exposures and various outcomes, including mortality and serious morbidity effects
 - Recent U.S. and Canadian epidemiologic studies reporting positive and statistically significant health effect associations for PM_{2.5} air quality likely to be allowed by the current standards
 - Analyses of pseudo-design values indicating substantial portions of study area health events/populations in locations with air quality likely to have met the current PM_{2.5} standards
 - Risk assessment estimates that the current primary standards could allow thousands of PM_{2.5}-associated deaths per year – most at annual average PM_{2.5} concentrations from 10 to 12 µg/m³ (well within the range of overall mean concentrations in key epidemiologic studies)

Preliminary Conclusions on the Current Primary PM_{2.5} Standards (Continued)

- In contrast, a conclusion that the current primary PM_{2.5} standards do provide adequate health protection would place little weight on the epidemiologic evidence or the risk assessment
- Such a conclusion would place greater weight on uncertainties and limitations, including:
 - Increasing uncertainty in the biological pathways through which PM_{2.5} exposures could cause serious health effects as the ambient concentrations being considered fall farther below the PM_{2.5} exposure concentrations shown to cause effects in experimental studies
 - Increasing uncertainty in the potential public health impacts of air quality improvements as the ambient concentrations being considered fall farther below those present in accountability studies that document improving health with declining PM_{2.5}
 - Accountability studies evaluate air quality improvements with “starting” mean PM_{2.5} concentrations (i.e., prior to the reductions evaluated) from ~13 to > 20 µg/m³
 - Uncertainty in the risk assessment results from uncertainties in the underlying epidemiologic studies, in the air quality adjustments, and in the application of study and air quality information to develop quantitative estimates of PM_{2.5}-associated mortality risks

Preliminary Conclusions on the Annual Standard Level

- If consideration is given to revising the primary PM_{2.5} standards to increase public health protection, it would be appropriate to focus on lowering the level of the annual standard
- Support for particular levels depends on the weight placed on various aspects of the science and uncertainties
- For example, a level as low as 10.0 µg/m³ could be considered if weight is placed on:
 - Setting a standard to maintain mean PM_{2.5} concentrations below those in most key U.S. epidemiologic studies
 - Setting the standard level at or below the pseudo-design values corresponding to about the 50th percentiles of study area health event/populations in key U.S. studies
 - Setting a standard estimated to reduce PM_{2.5}-associated health risks, such that a substantial portion of the risk reduction is estimated at annual average PM_{2.5} concentrations ≥ ~8 µg/m³
- A level below 10.0 µg/m³, potentially as low as 8.0 µg/m³, could be supported to the extent more weight is placed on PM_{2.5} health effect associations and estimated risks at lower concentrations and less weight is placed on uncertainties at lower concentrations

Preliminary Conclusions on the 24-Hour Standard Level

- Purpose of the 24-hour standard is to provide protection against the short-term exposures to peak PM_{2.5} concentrations, such as those that can occur in areas with strong contributions from local or seasonal sources even when overall mean concentrations remain relatively low
- In considering potential support for additional protection against short-term exposures to “peak” concentrations, we focus on the evidence from key epidemiologic studies and human clinical studies
 - Key epidemiologic studies do not indicate that PM_{2.5} health effect associations are driven disproportionately by peak concentrations
 - Human clinical studies report effects following single short-term PM_{2.5} exposures, but these studies generally examine exposures well above those measured in areas meeting the current standards
- Thus, the evidence provides little support for the need to provide additional protection against short-term peak concentrations in areas meeting the current 24-hour standard and the current, or revised (i.e., with a lower level), annual standard

Additional Information

Two-Hour PM_{2.5} Concentrations

- In human clinical studies, statistically significant effects on one or more indicators of cardiovascular function are often, though not always, reported following 2-hour exposures to average PM_{2.5} concentrations at and above about 120 µg/m³
- There is less consistent evidence for effects following exposures to lower concentrations

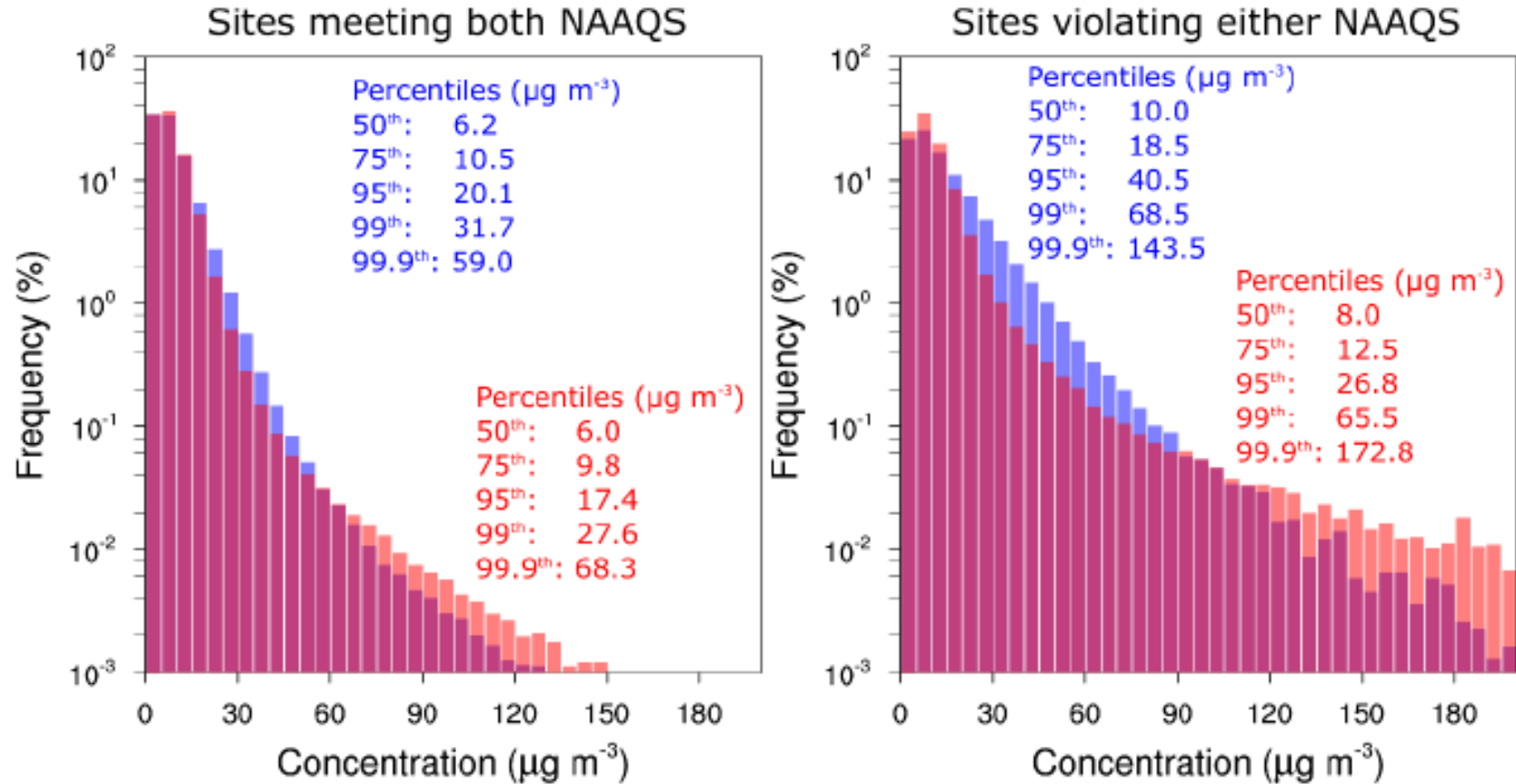
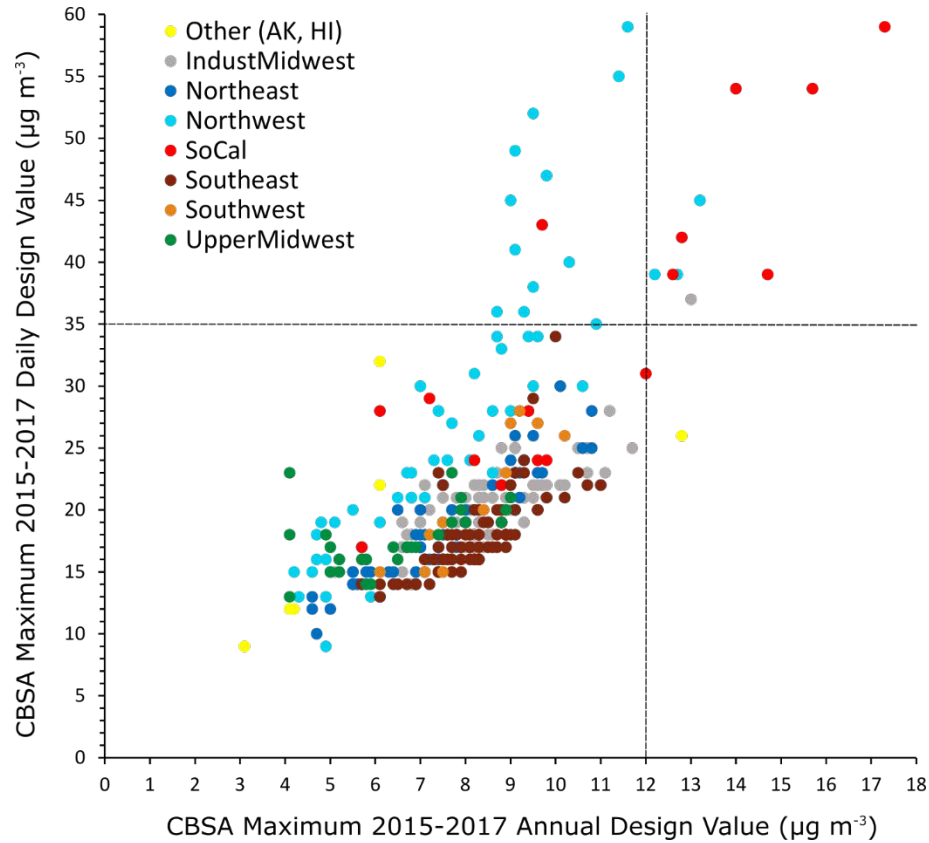


Figure 2-14. Frequency distribution of 2015-2017 2-hour averages for sites meeting or violating the annual PM_{2.5} NAAQS for October to March (blue) and April to September (red).

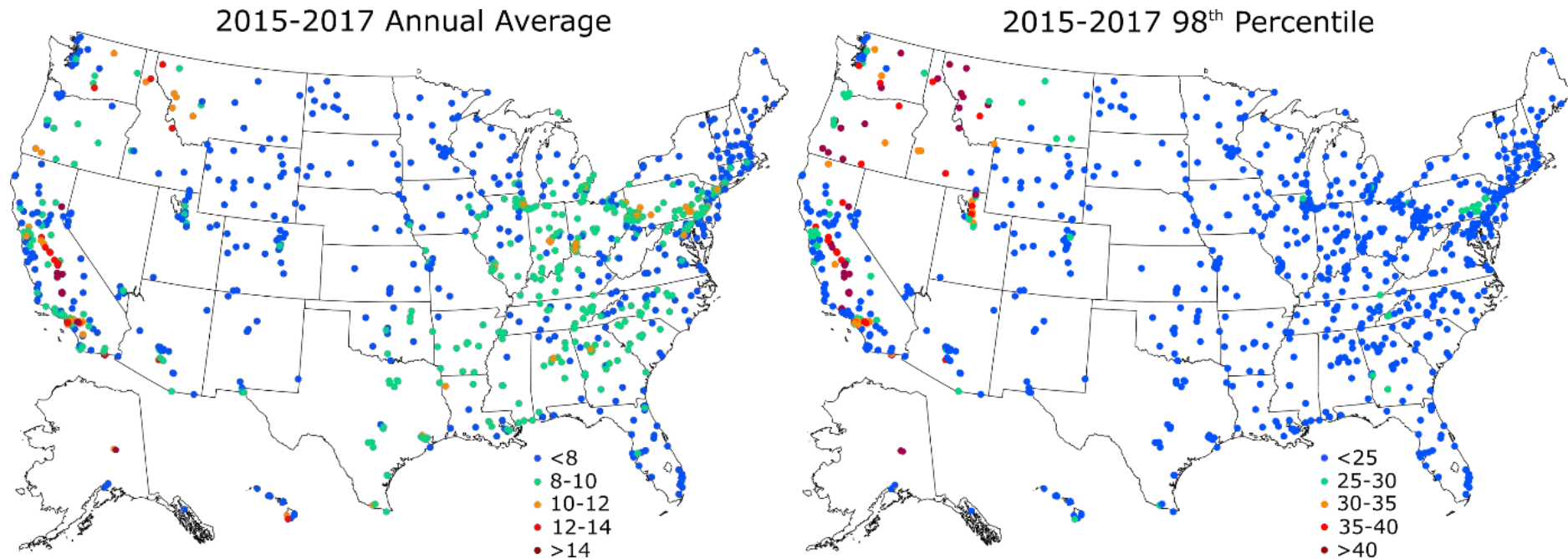
Annual and 24-Hour DVs



It is likely that some of the annual and daily design values above are impacted by potential exceptional events associated with wildfire smoke that have yet to be removed from the calculations.

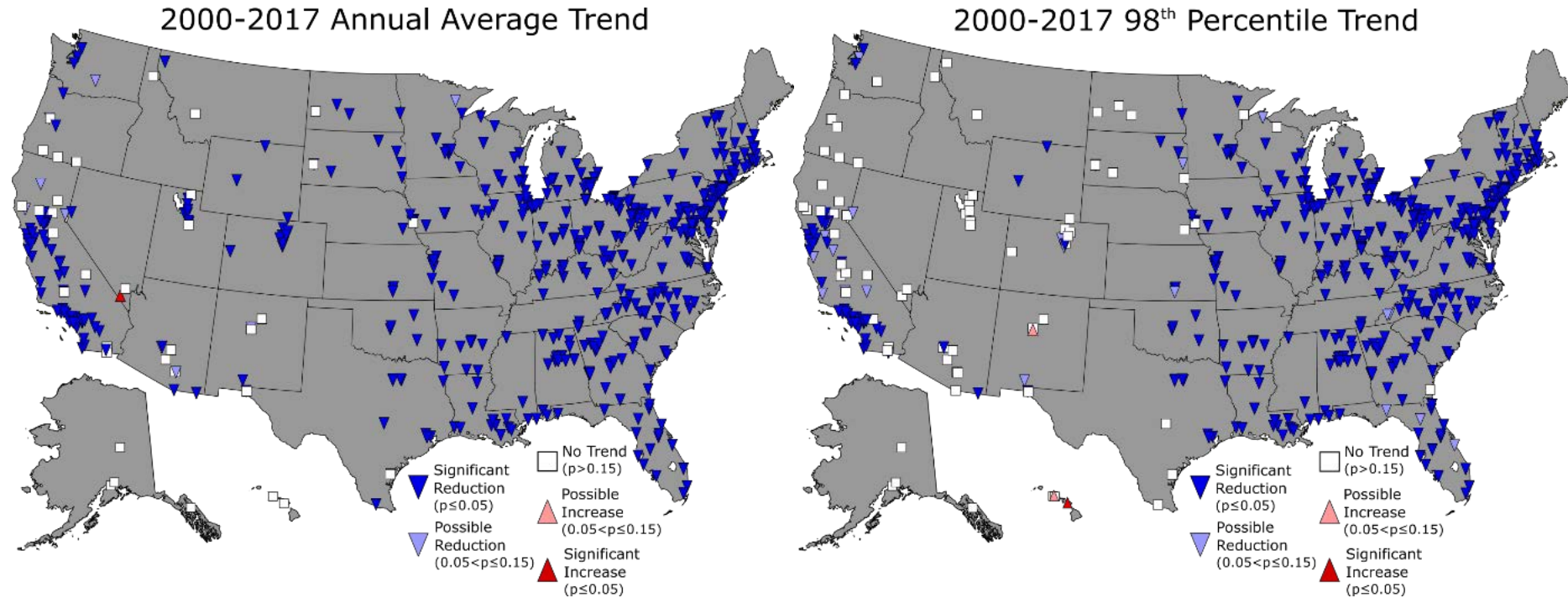
Draft PA Figure 2-11

PM_{2.5}: Recent Concentrations



- Highest annual average and 98th percentile PM_{2.5} concentrations are in California
- Fires in the Northwest were frequent during the 2015-2017 period
- Most Eastern sites had annual average and 98th percentile values below 10 and 25 $\mu\text{g m}^{-3}$, respectively

PM_{2.5} Trends



- The annual average and 98th percentile values have decreased over much of the Eastern US since 2000
- In the Western US, many sites have had no trend in the 98th percentile values in part because of the impact of meteorology and wildfires

Key PM_{2.5}-Related Health Outcomes Considered in the Draft PA

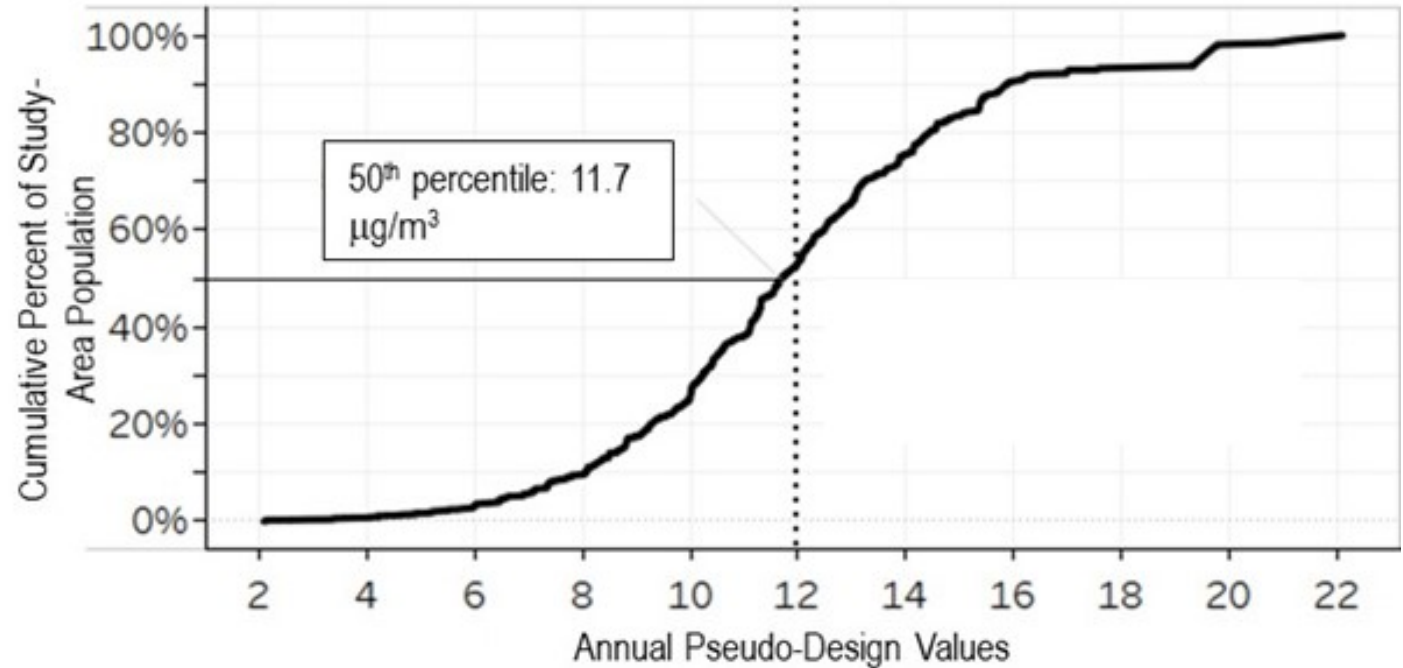
Exposure Duration	Outcome	2009 ISA Conclusion	2018 Draft ISA Conclusion
Long-Term	Mortality	Causal	Causal
	Cardiovascular	Causal	Causal
	Respiratory	Likely to be causal	Likely to be causal
	Cancer	Suggestive	Likely to be causal
	Nervous System	None	Likely to be causal
Short-Term	Mortality	Causal	Causal
	Cardiovascular	Causal	Causal
	Respiratory	Likely to be causal	Likely to be causal

Calculation of PM_{2.5} Pseudo-Design Values

Approach

- Identify study areas (counties/cities) with sufficient monitoring data to calculate pseudo-design values
- For each monitored area and each 3-yr period of the study, identify the highest monitored PM_{2.5} value
- For each monitored area, calculate the study-period average of these highest values
- Link study locations to study populations or health events
- Arrange study locations by ascending pseudo-design values
- Identify the cumulative percent of population or health events in study locations with various pseudo-design values

Example for Di et al. (2017)





Particulate Matter: Spotlight on Health Protection



Phil Martien, Ph.D.

- Director of the Assessment, Inventory, & Modeling Division at the Bay Area Air Quality Management District
- Leading role in the Technical Assessment of AB617's West Oakland Community Action Plan
- Leading role in the Technical Assessment of the Air District's 2017 Clean Air Plan: Spare the Air, Cool the Climate
- Leading role in the Air District's Community Air Risk Evaluation Program
- Ph.D. from UC Berkeley

Targeting Particulate Matter: West Oakland Community Emissions Reduction Program

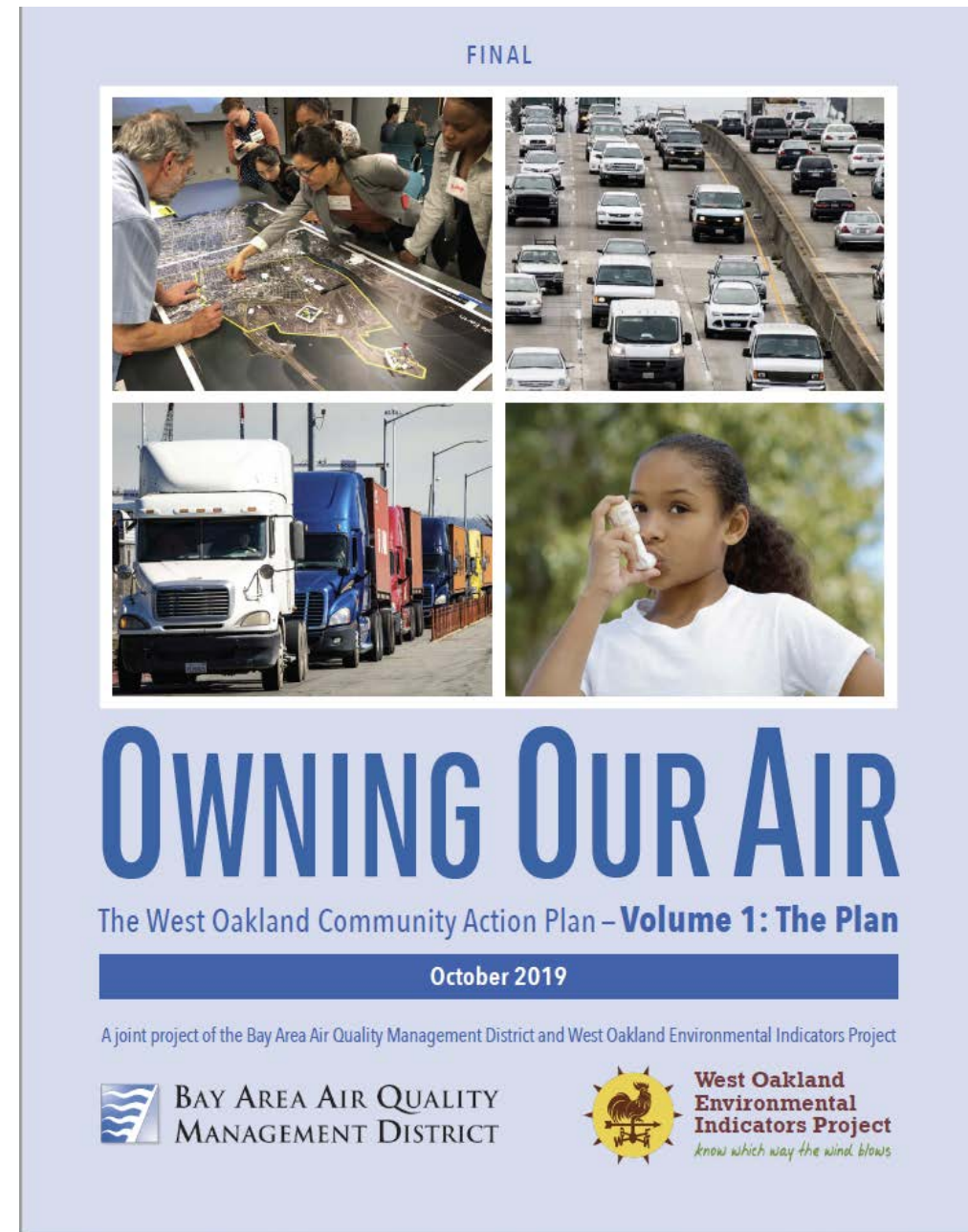


**West Oakland
Environmental
Indicators Project**
know which way the wind blows

Phil Martien, PhD
Bay Area Air Quality Management District
Particulate Matter: Spotlight on Health Protection
October 28, 2019

Acknowledgements

- Bay Area Air Quality Management District
- West Oakland Environmental Indicators Project
- West Oakland Steering Committee
- California Air Resources Board



Assessment of Particulate Matter (PM) in West Oakland

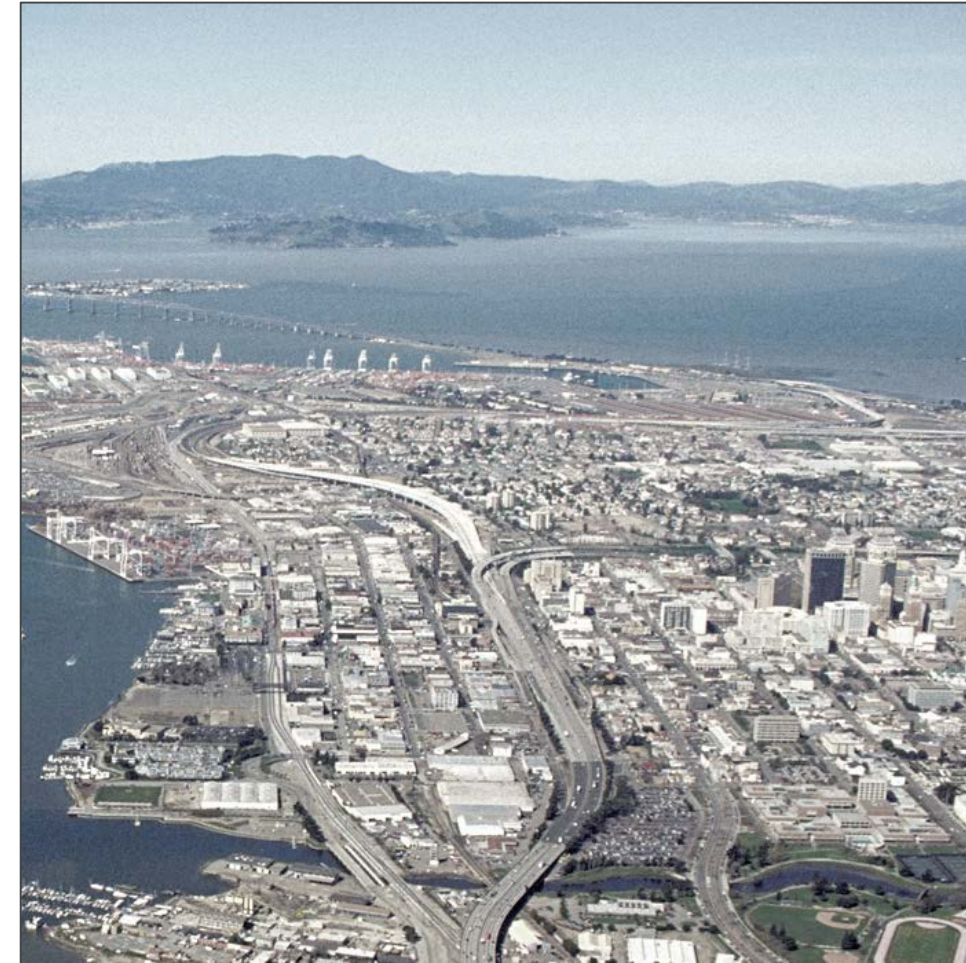
■ Motivation

- Implementing Assembly Bill (AB) 617: West Oakland Community Emissions Reduction Program

■ Modeling-based assessment approach

■ Findings

- Source contributions to impacts
- Equity-based targets
- Effective emission reduction measures



West Oakland

Motivation

Implementing AB 617

- Address environmental justice concerns: higher air pollution in some communities
- Key mandates:
 - Local air districts to partner with community groups
 - Identify top sources of community impacts
 - Develop and implement plans to reduce emissions



West Oakland: Year 1 Community Emissions Reduction Plan



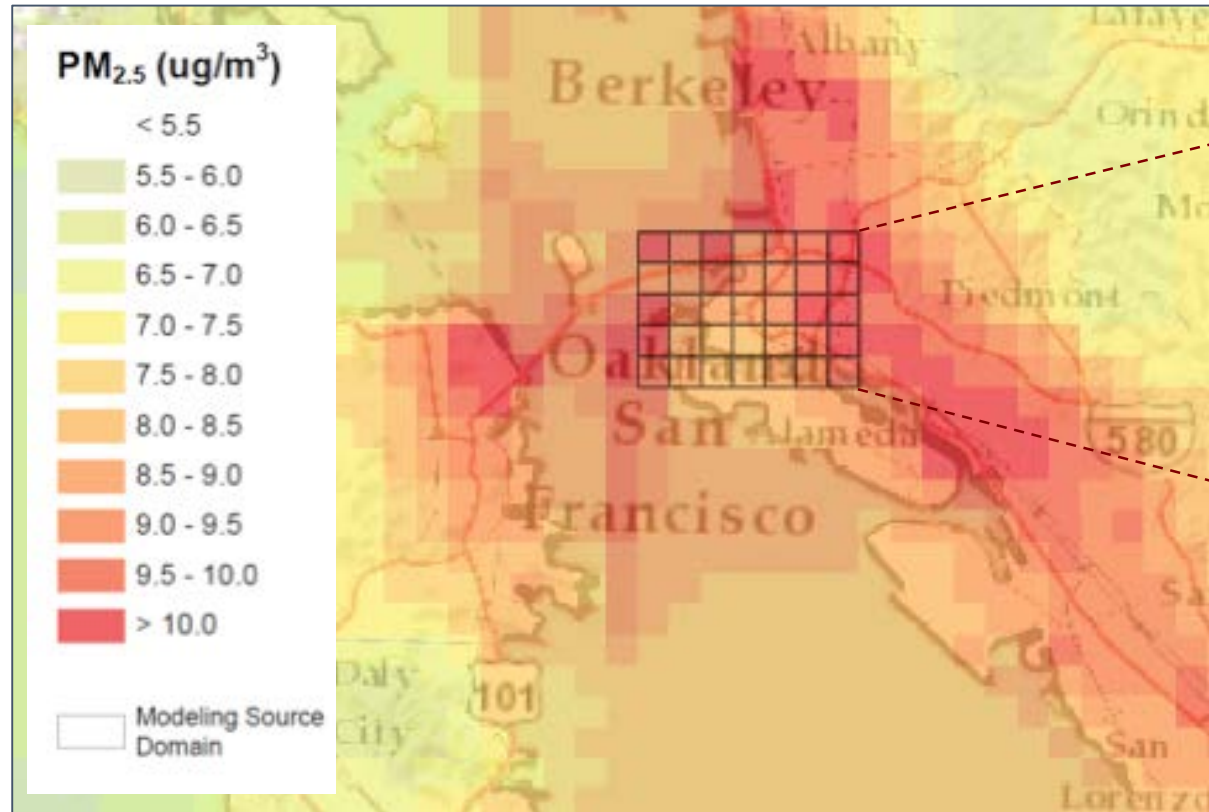
**West Oakland
Environmental
Indicators Project**
know which way the wind blows

- Established partner: WOEIP has decades of experience
- High mobile-source emissions
 - Adjacent to the Port of Oakland
 - Surrounded by the I-880, I-80, I-580, and I-980 freeways
 - Industrial sources
- High health burdens and socio-economic vulnerabilities

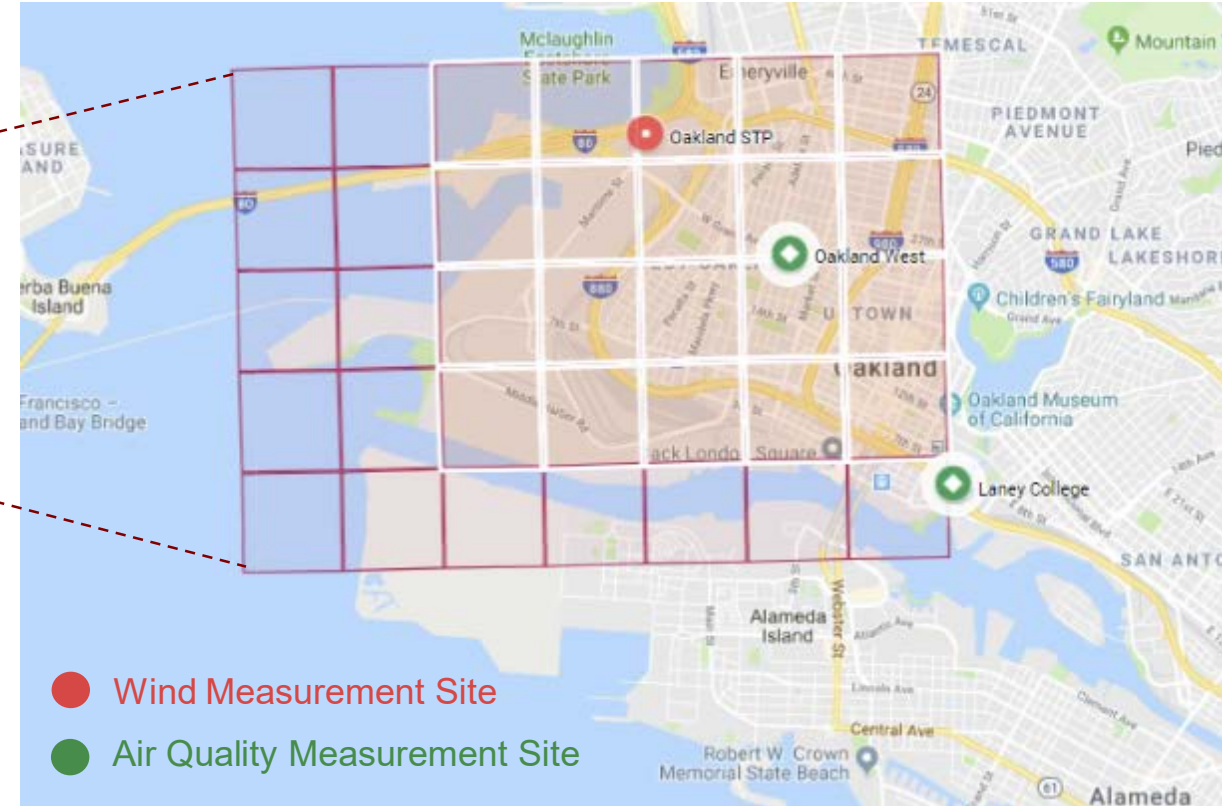


Assessment Approach

Regional-Scale and Community-Scale Modeling (2017)



Regional-scale modeling: covers the Bay Area



Local-scale modeling: covers West Oakland, including impacts in receptor area (white) from sources in source area (red)

Pollutants

- PM_{2.5}
- Diesel PM
- Air toxics (cancer risk)

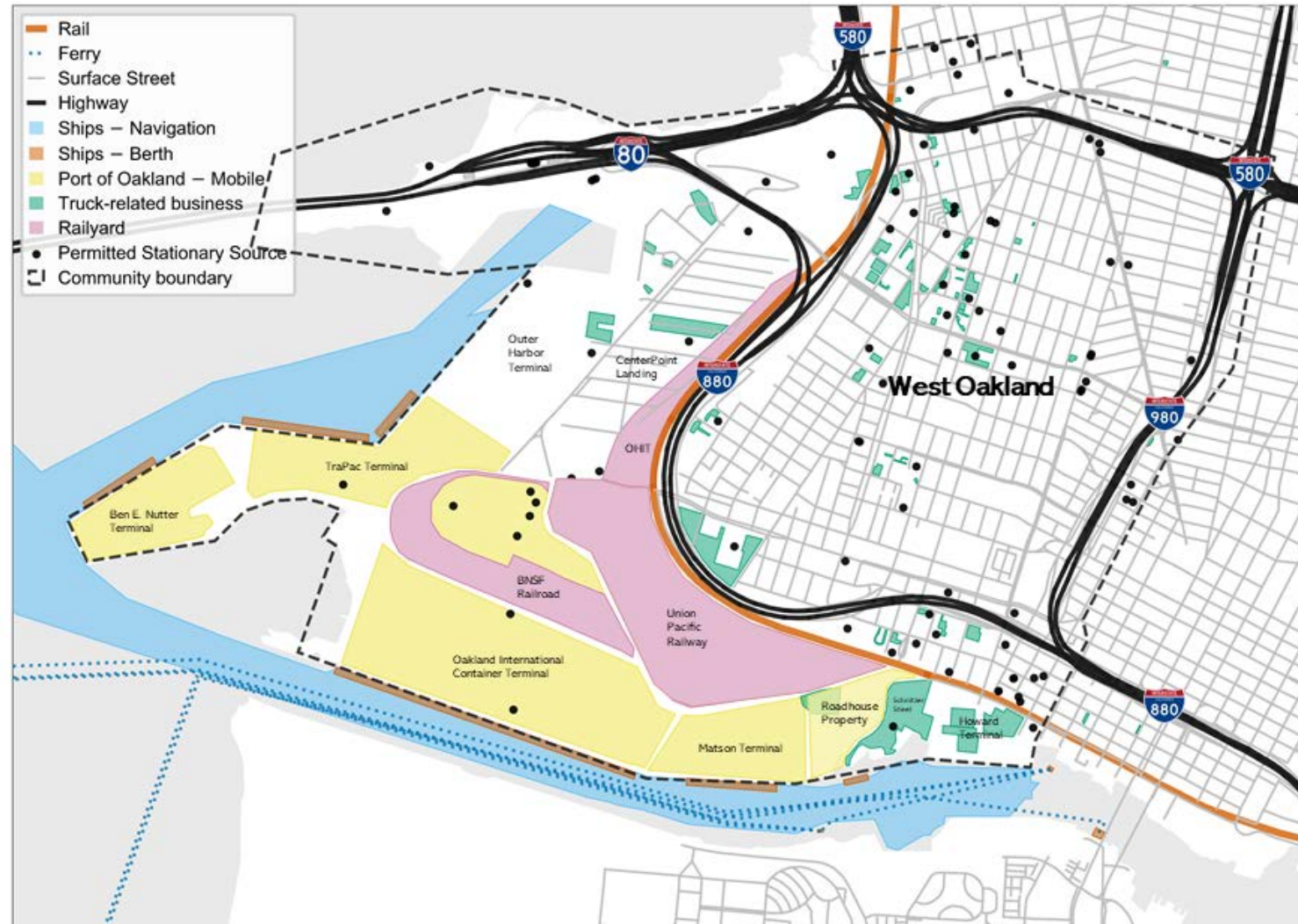
Sources modeled

- Port of Oakland and marine
- Railyards and trains
- Vehicles on freeways, streets
- Truck-related businesses
- Permitted stationary sources

Not modeled

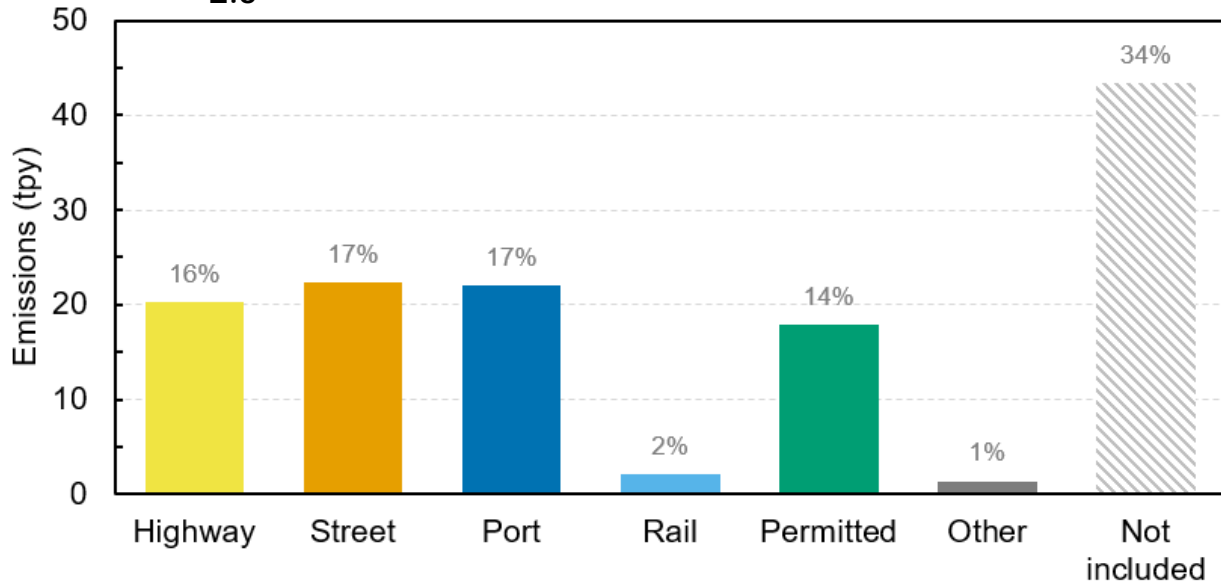
- Construction, residential woodburning, and restaurants

Community-Scale Modeling

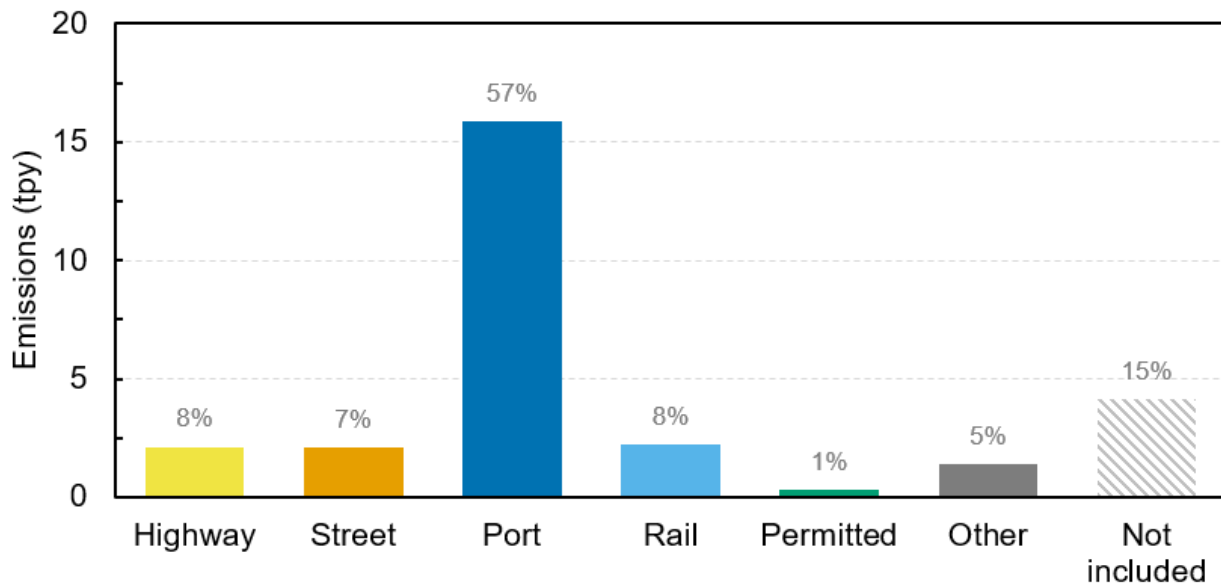


West Oakland Emissions by Source Category (2017)

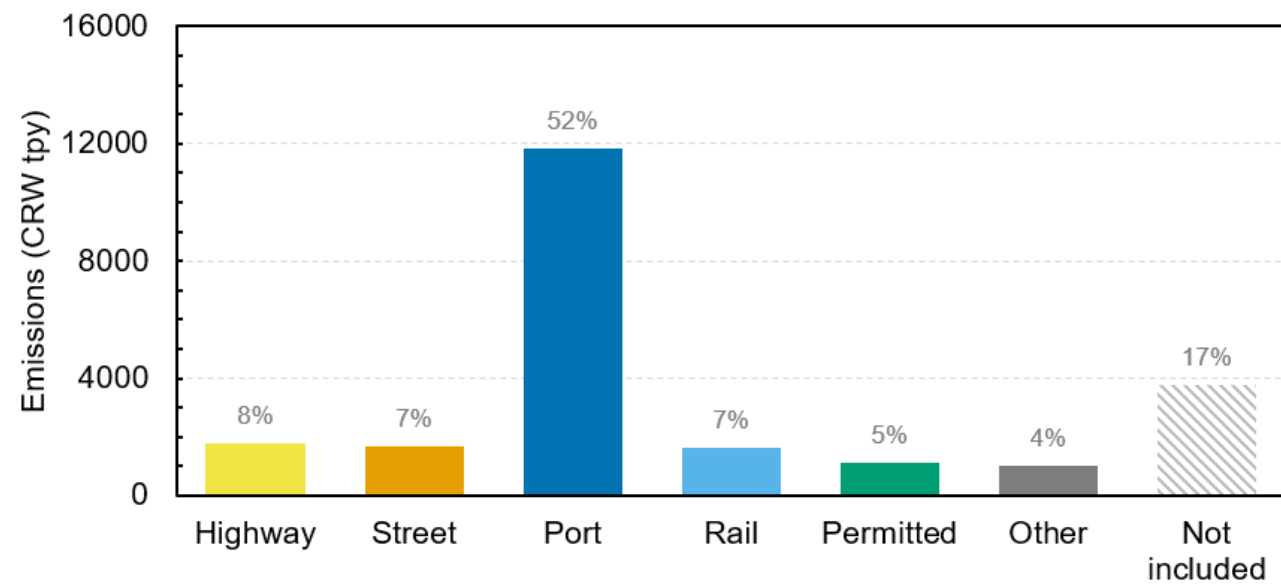
(a) PM_{2.5}



(b) Diesel PM



(c) Cancer risk-weighted toxics

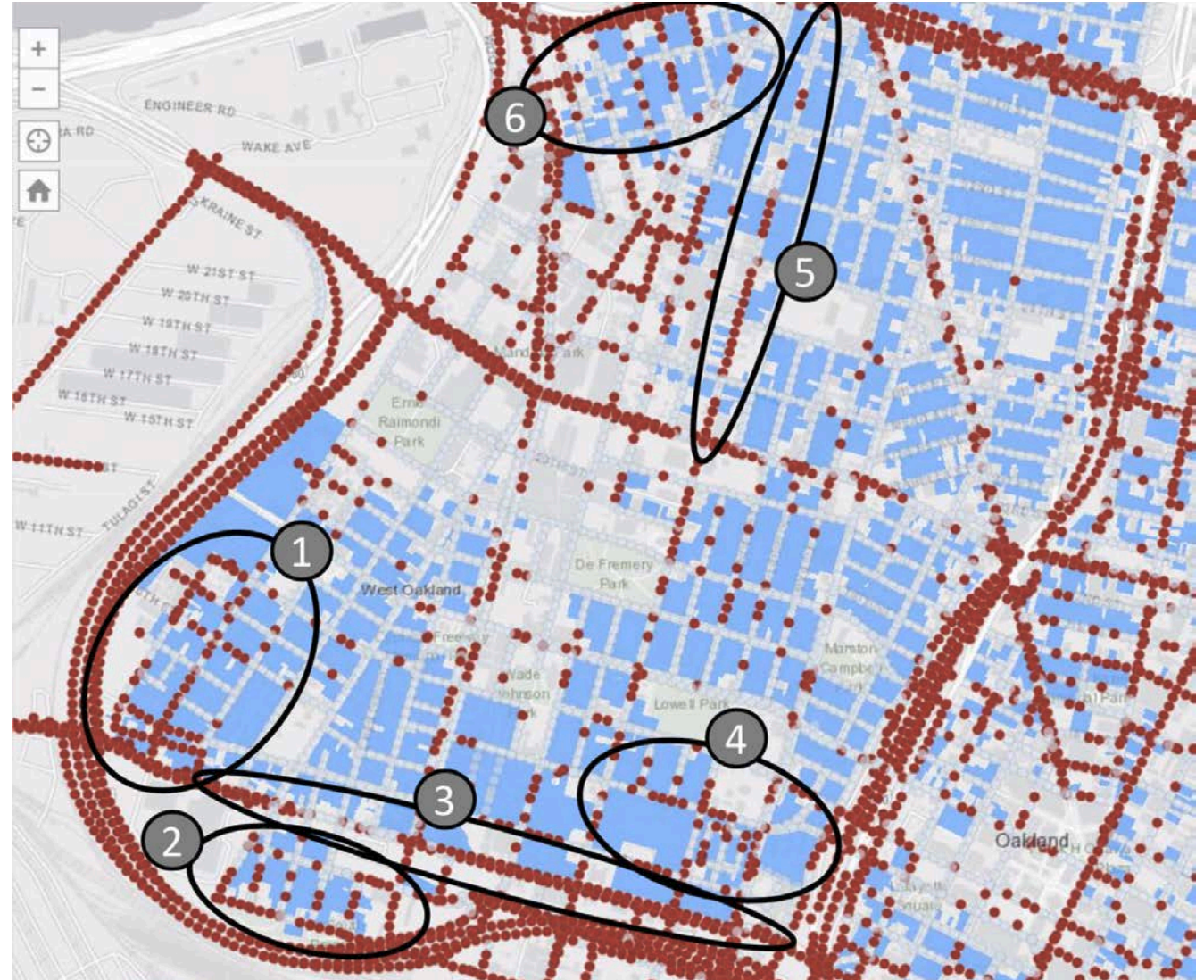


Impact Varies by Location

Local Impact Zones

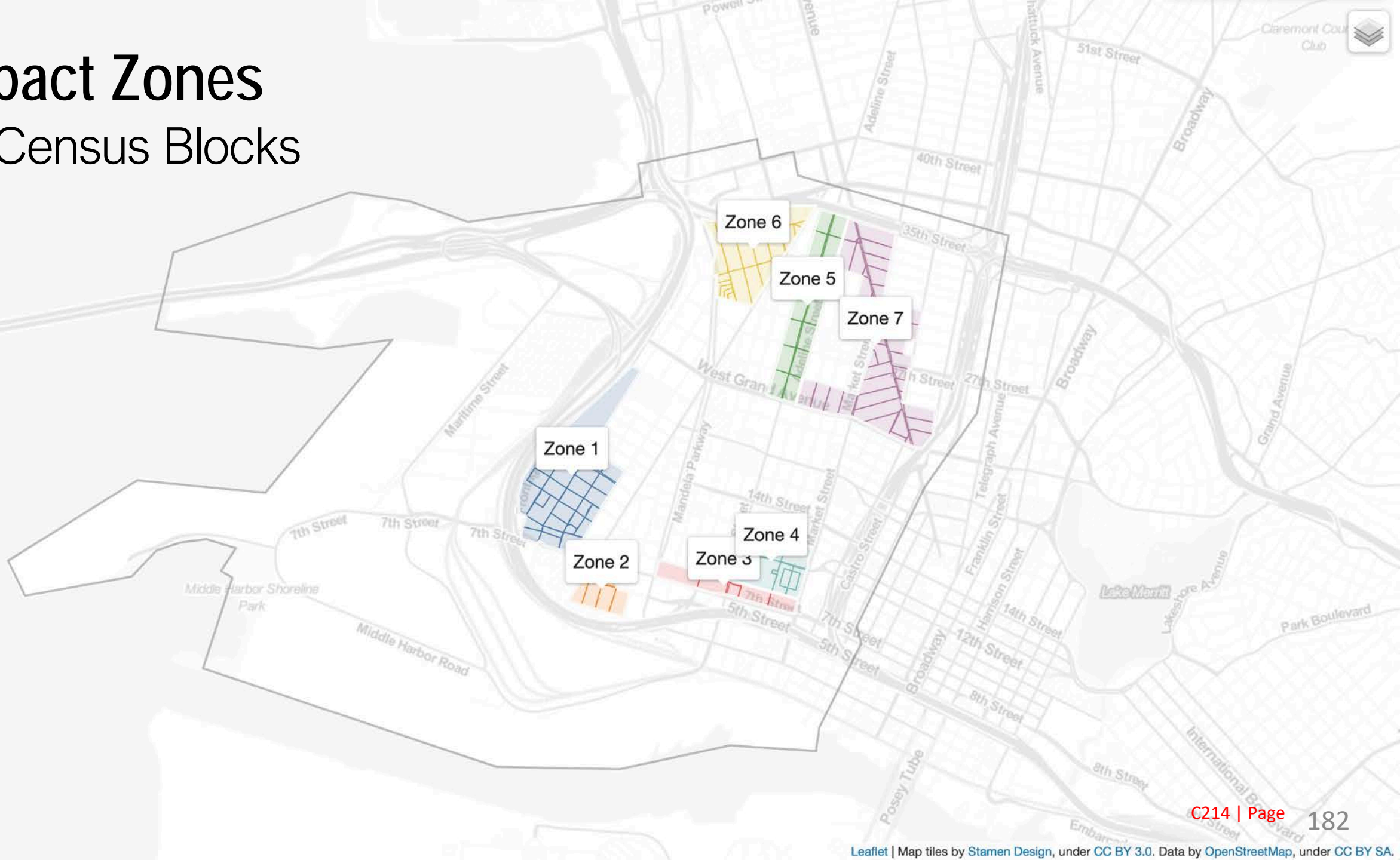
Local Impact Zones

- ① Lower bottom/West Prescott
- ② Third Street
- ③ Seventh Street
- ④ Acorn
- ⑤ Upper Adeline
- ⑥ Clawson
- ⑦ West Grand and San Pablo



Black Carbon above Median (Env. Def. Fund, 2019-01-13)

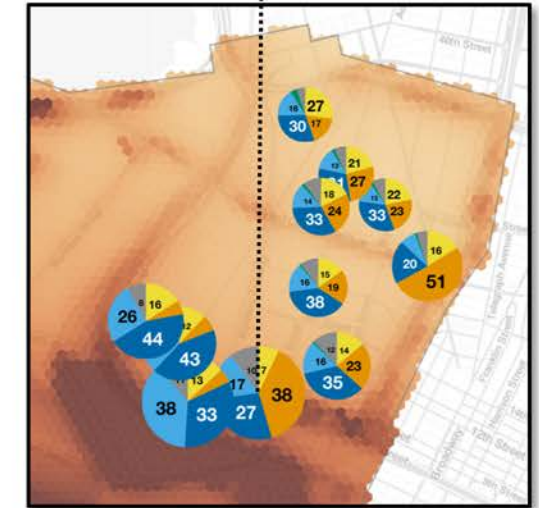
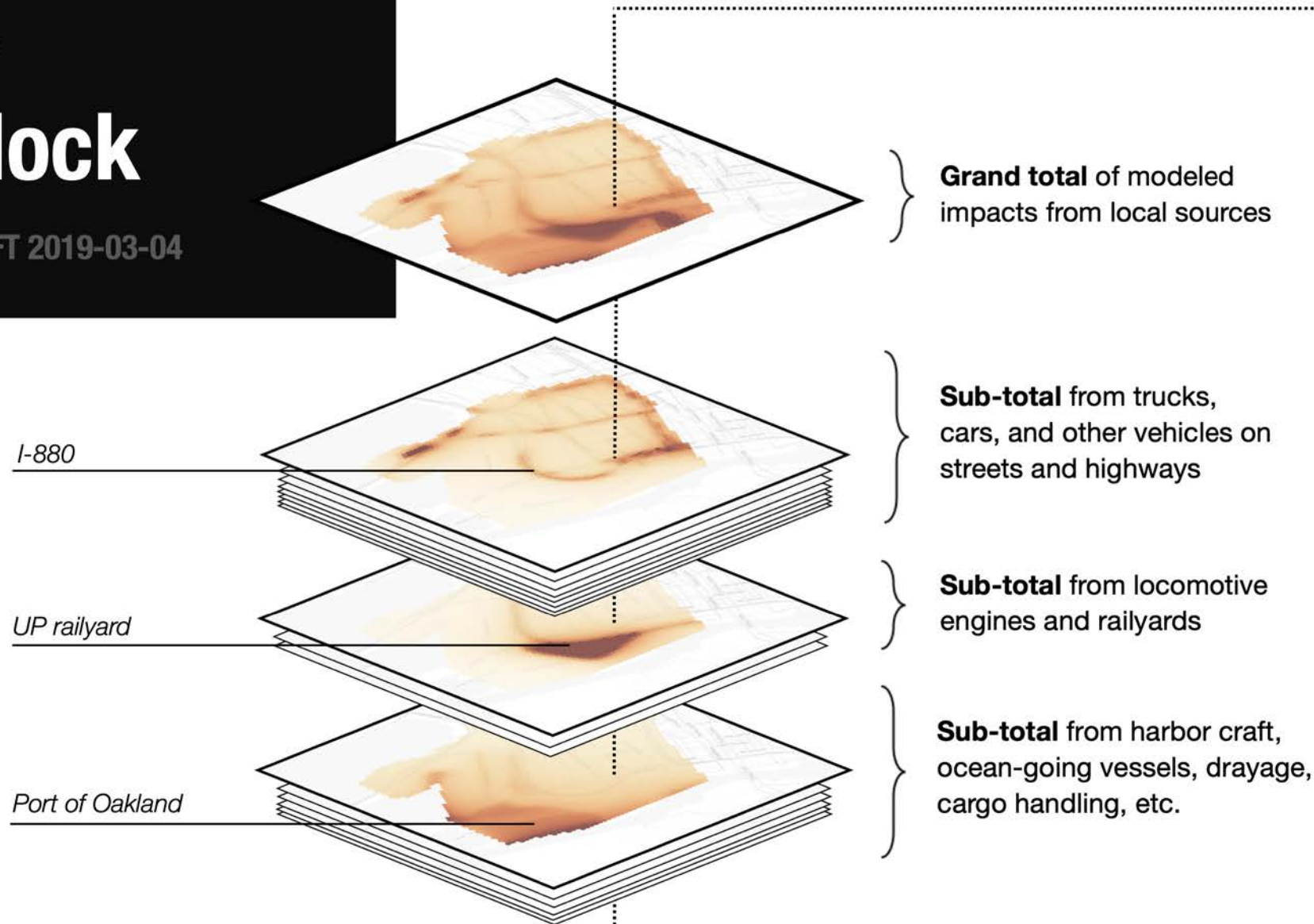
Impact Zones on Census Blocks



Source Apportionment

Block by Block

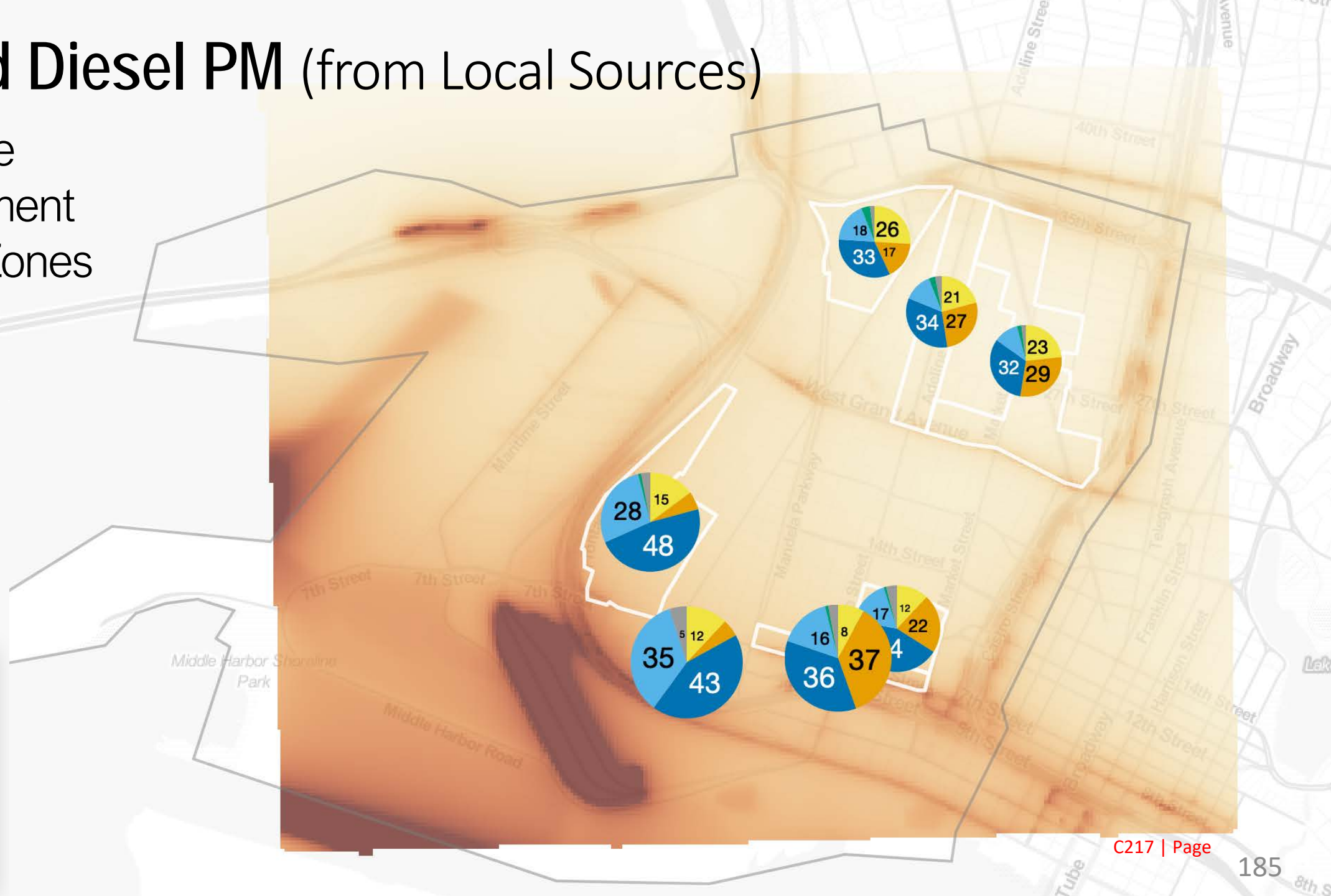
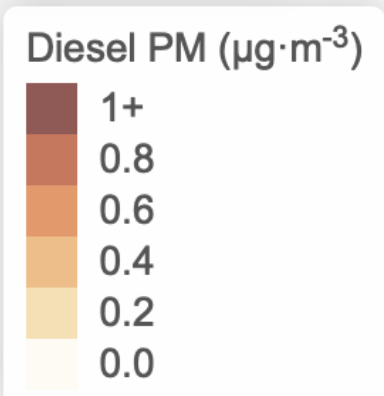
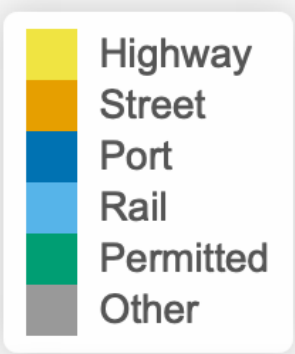
DRAFT 2019-03-04



For any location, we can use the sub-totals to draw piecharts showing the relative impacts of sources A, B, C, etc.

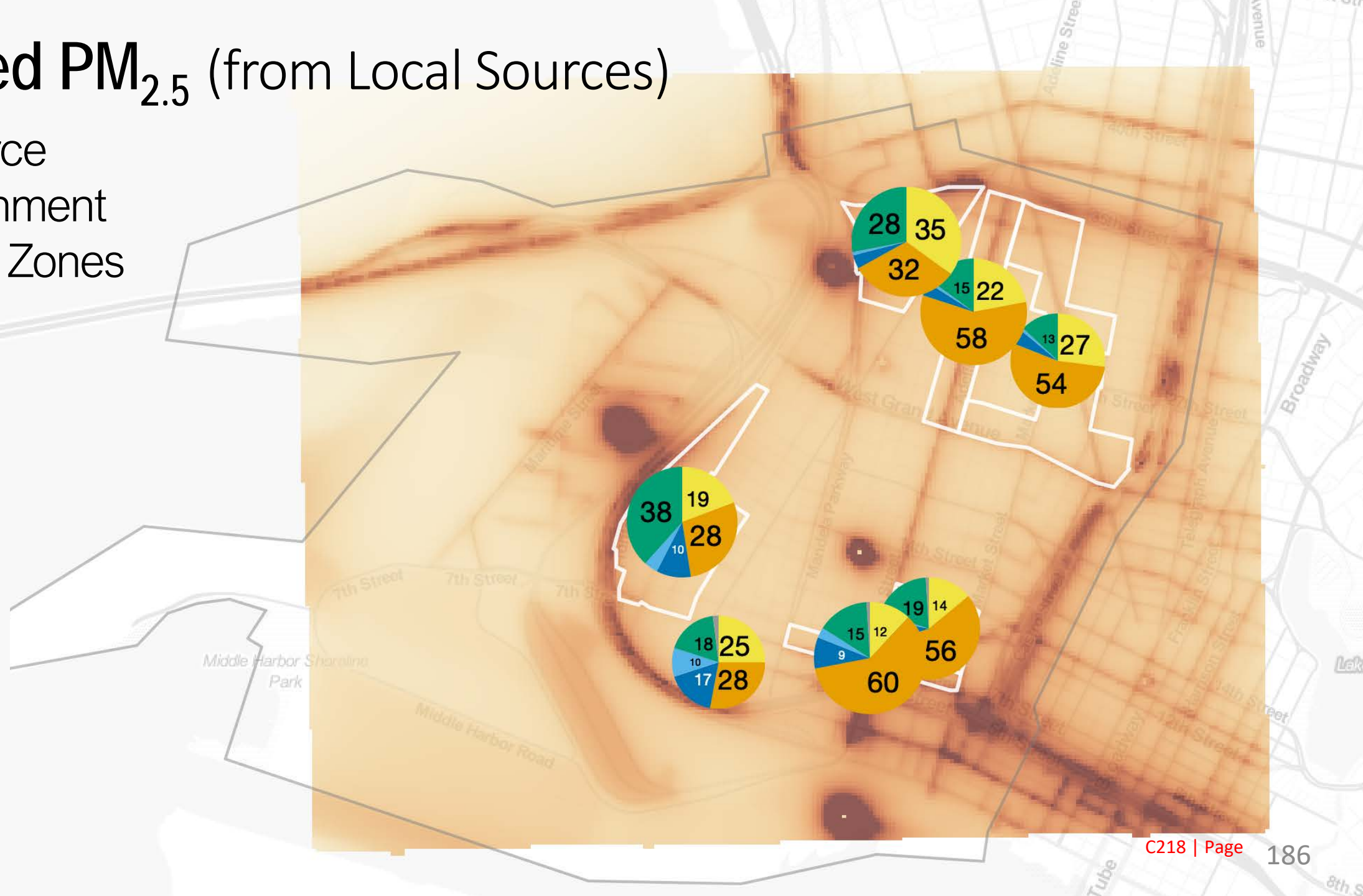
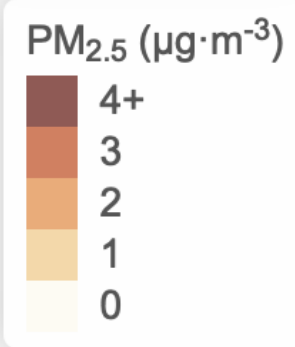
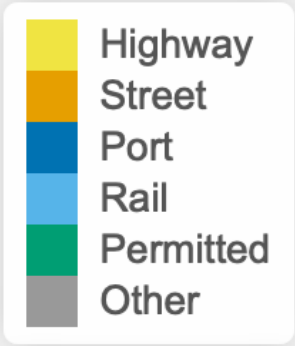
Modeled Diesel PM (from Local Sources)

with Source Apportionment in Impact Zones



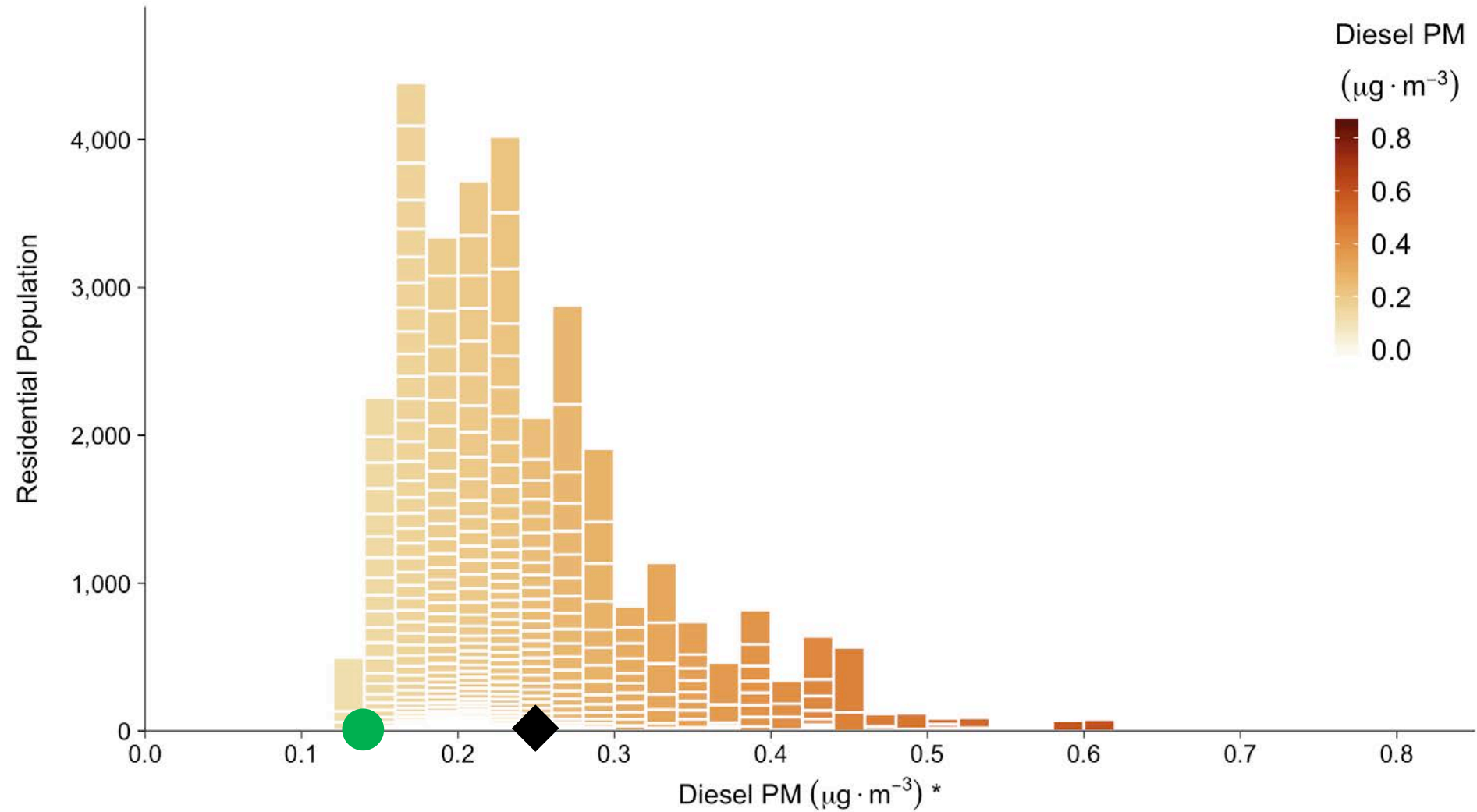
Modeled PM_{2.5} (from Local Sources)

with Source
Apportionment
in Impact Zones



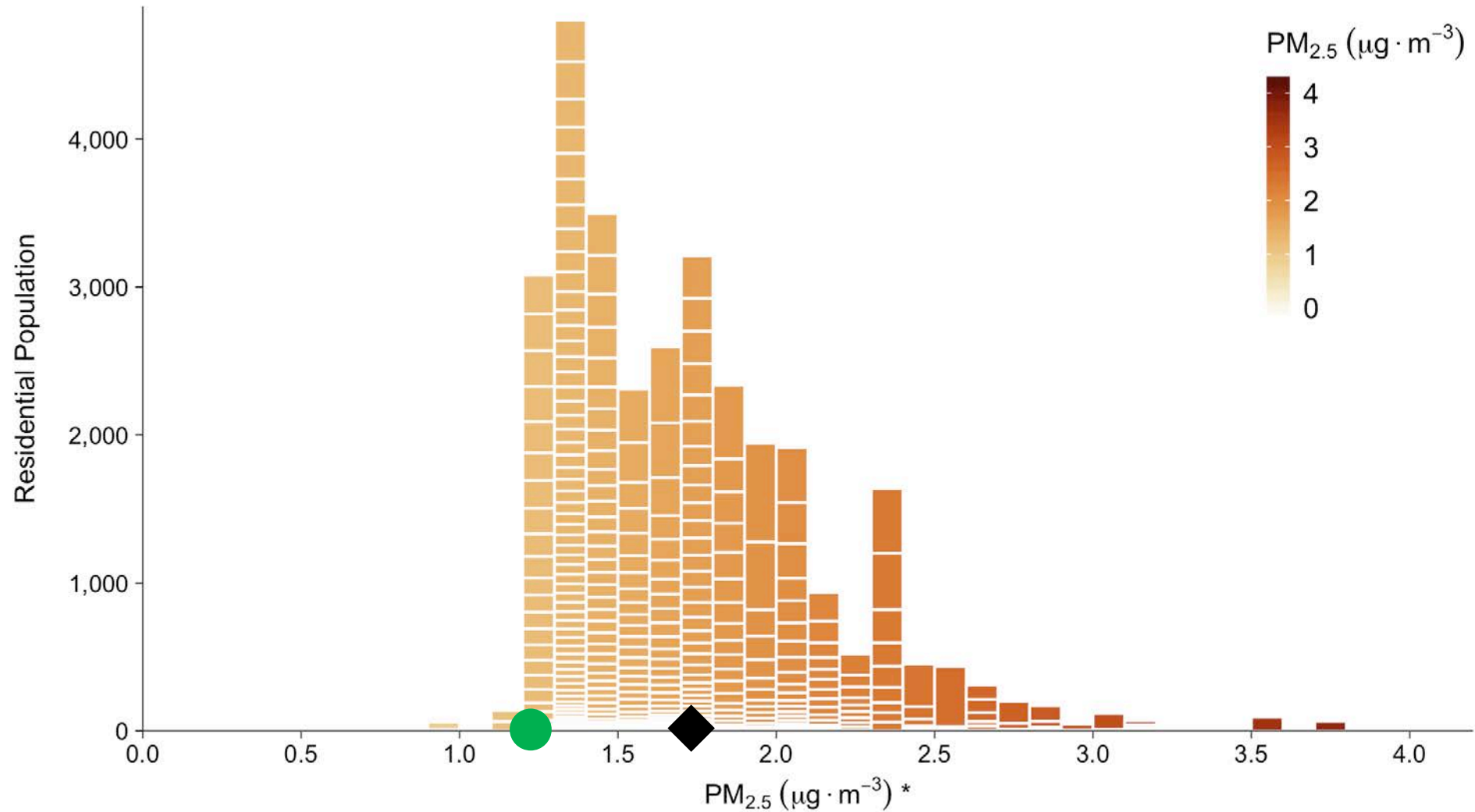
Equity-Based Targets

Unequal Impacts: Diesel PM Across West Oakland



* Contributed by modeled "present-day" emissions from existing local sources. Impacts from sources outside West Oakland not included.

Unequal Impacts: PM_{2.5} Across West Oakland



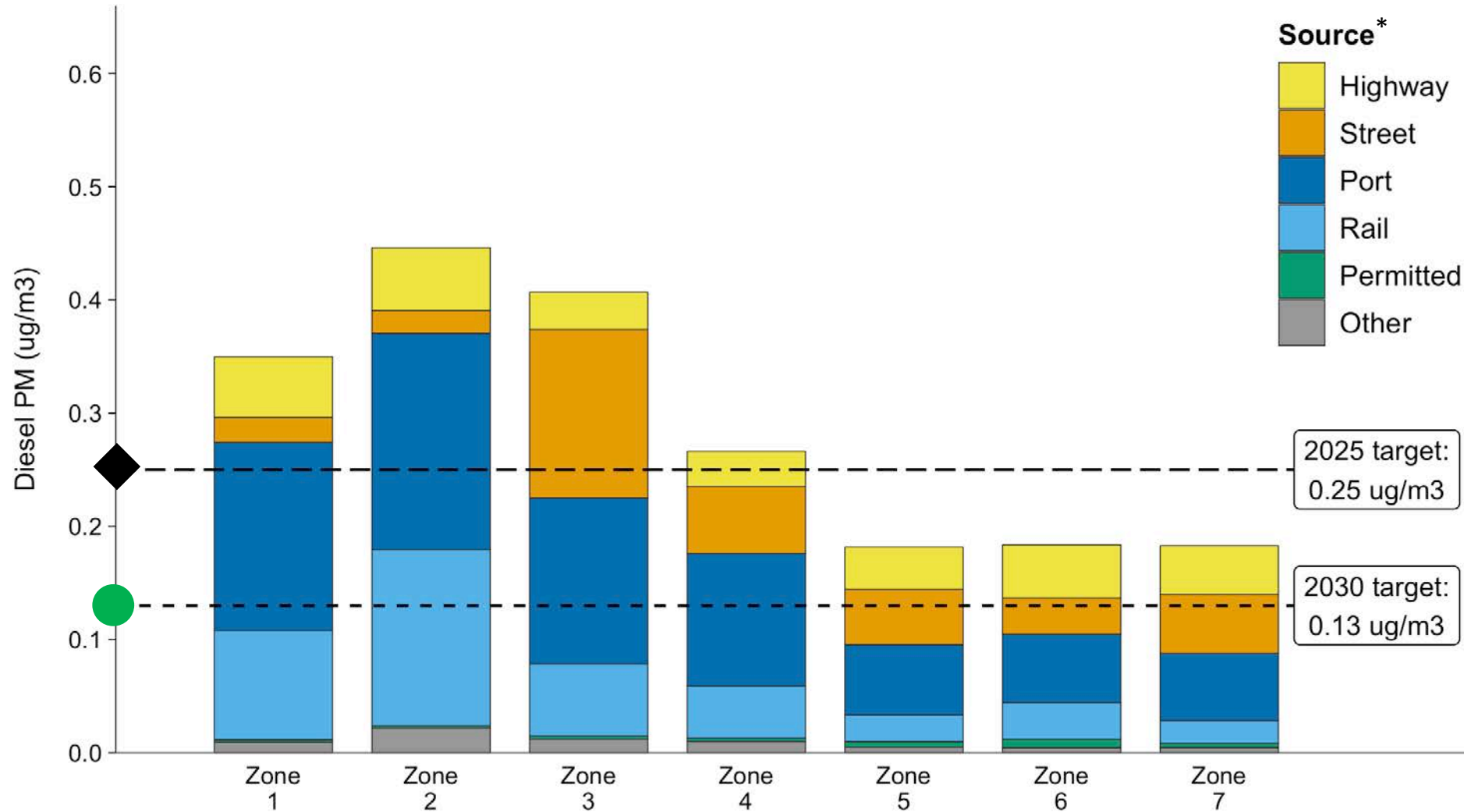
* Contributed by modeled "present-day" emissions from existing local sources. Impacts from sources outside West Oakland not included.

Targets and Source Contributions for Diesel PM

Targets:

2025 – Today's *average* residential neighborhood

2030 – Today's *cleanest* residential neighborhood



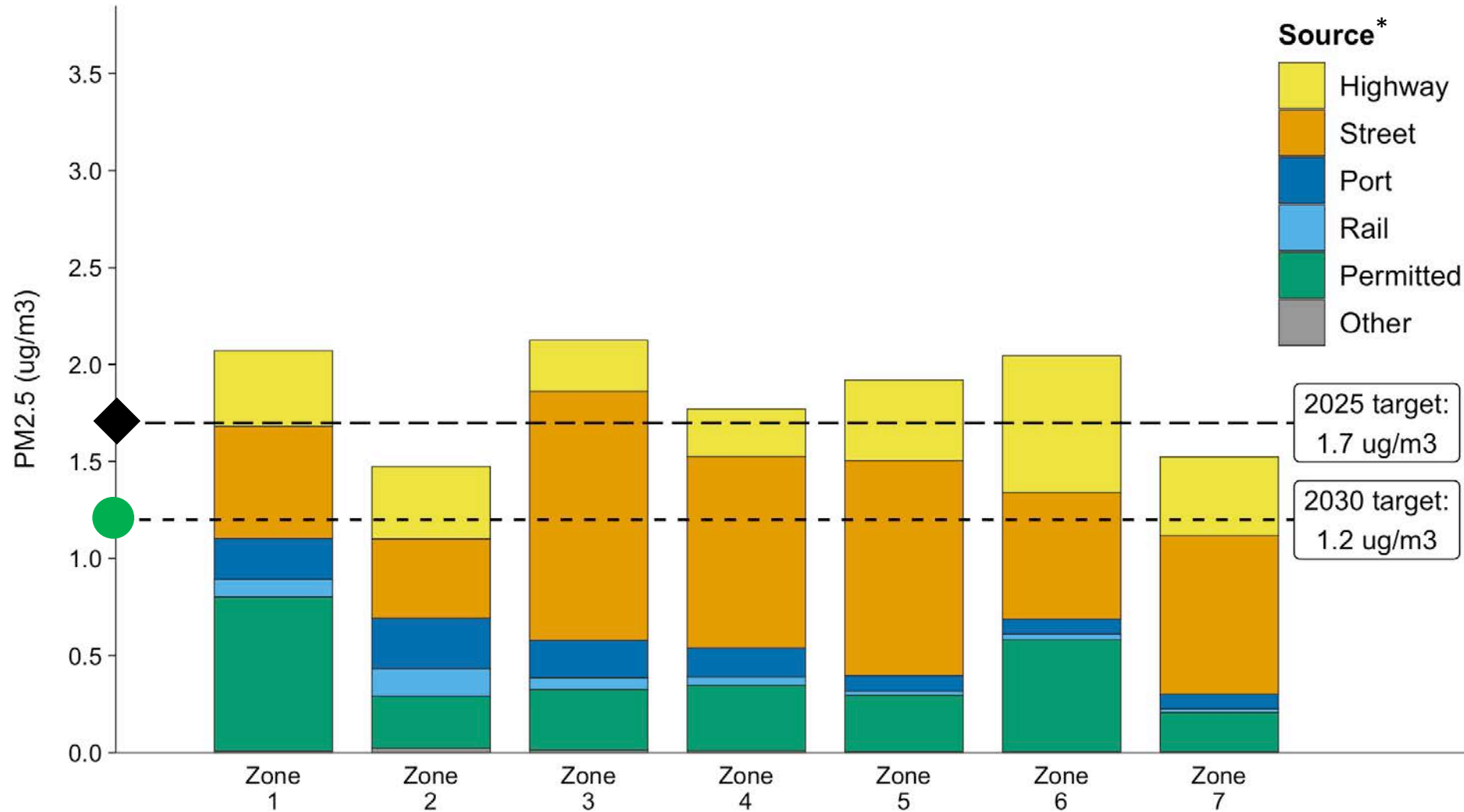
* Contributed by emissions from modeled local sources. Impacts from sources outside West Oakland not included.

Targets and Source Contributions for PM_{2.5}

Targets:

2025 – Today's *average* residential neighborhood

2030 – Today's *cleanest* residential neighborhood



* Contributed by emissions from modeled local sources. Impacts from sources outside West Oakland not included.

Impact Per Ton Varies by Source

What Moves the Needle?

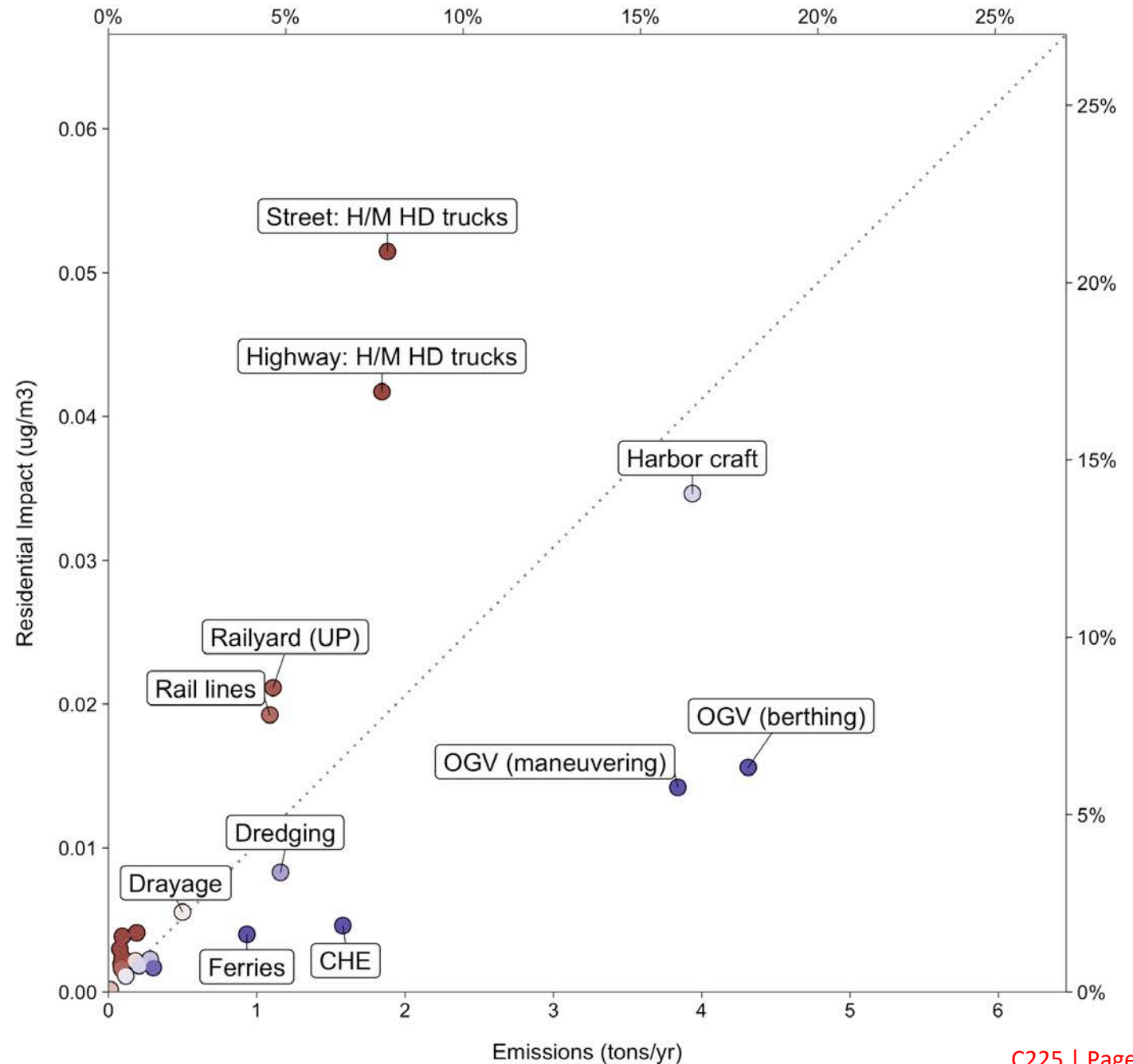
Impact Per Ton: Diesel PM in West Oakland

Circles are modeled local sources.

Red is more impact.

Blue is less impact.

Percentages are shares of modeled impact.



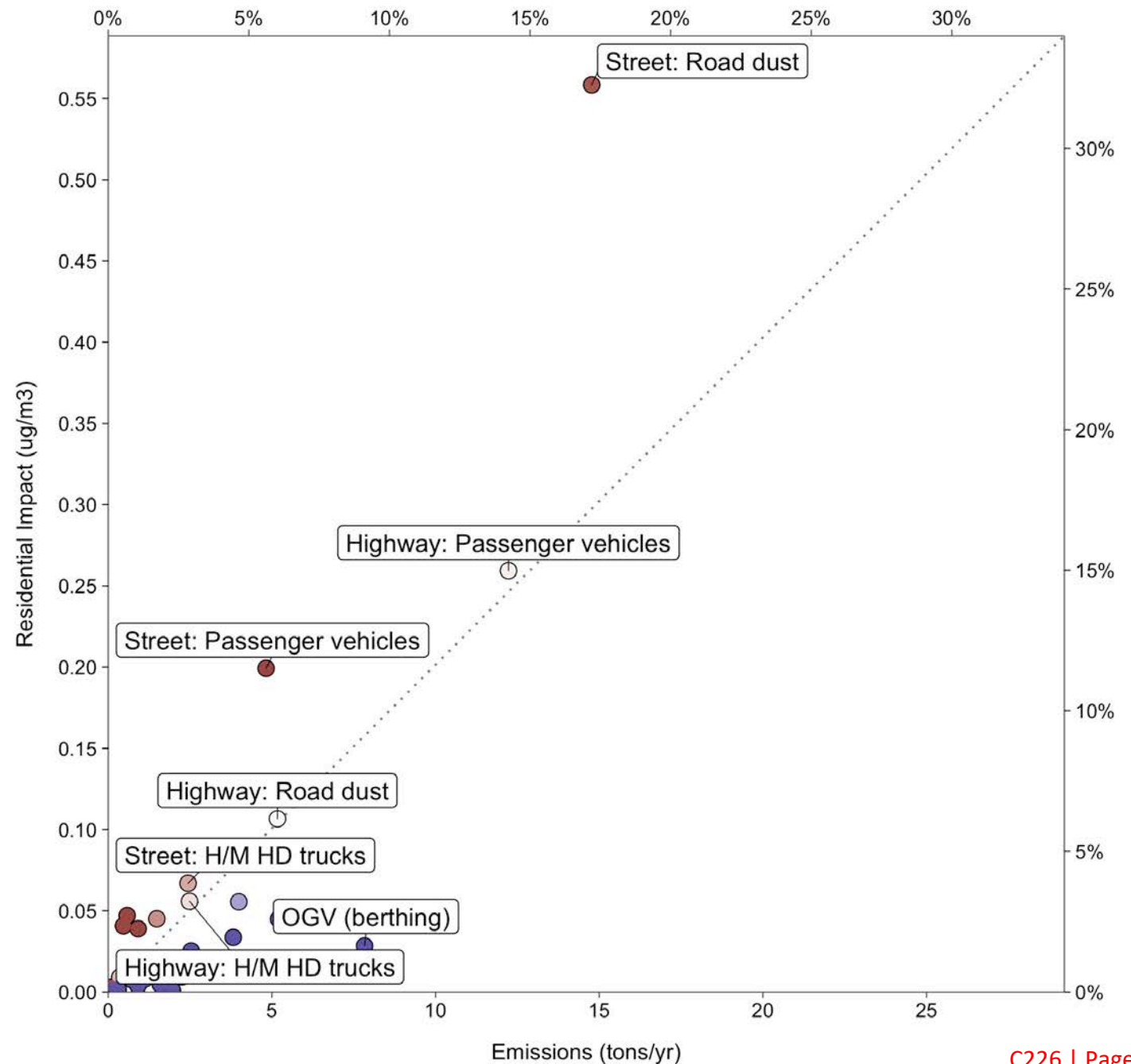
Impact Per Ton: PM_{2.5} in West Oakland

Circles are modeled local sources.

Red is more impact.

Blue is less impact.


Percentages are shares of modeled impact.



More Information

- baaqmd.gov/communityhealth/community-health-protection-program/
- woeip.org/
- arb.ca.gov/ourwork/programs/community-air-protection-program
- pmartien@baaqmd.gov

FINAL




OWNING OUR AIR


The West Oakland Community Action Plan – **Volume 1: The Plan**

October 2019

A joint project of the Bay Area Air Quality Management District and West Oakland Environmental Indicators Project



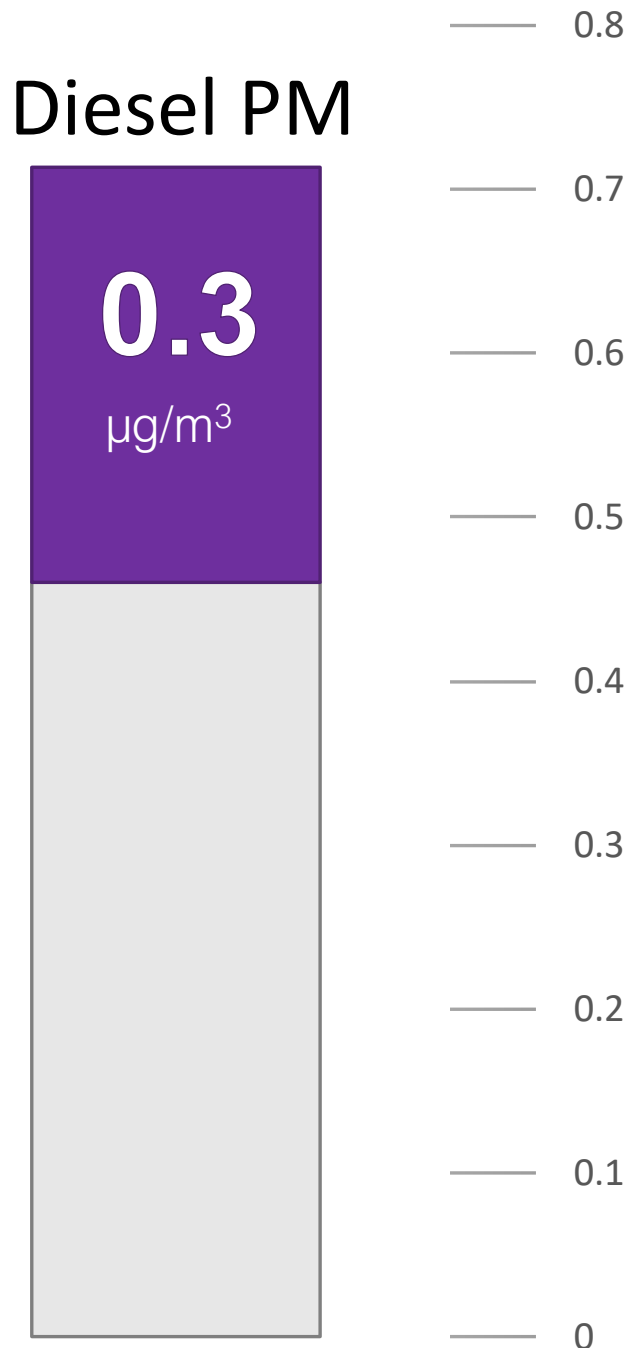
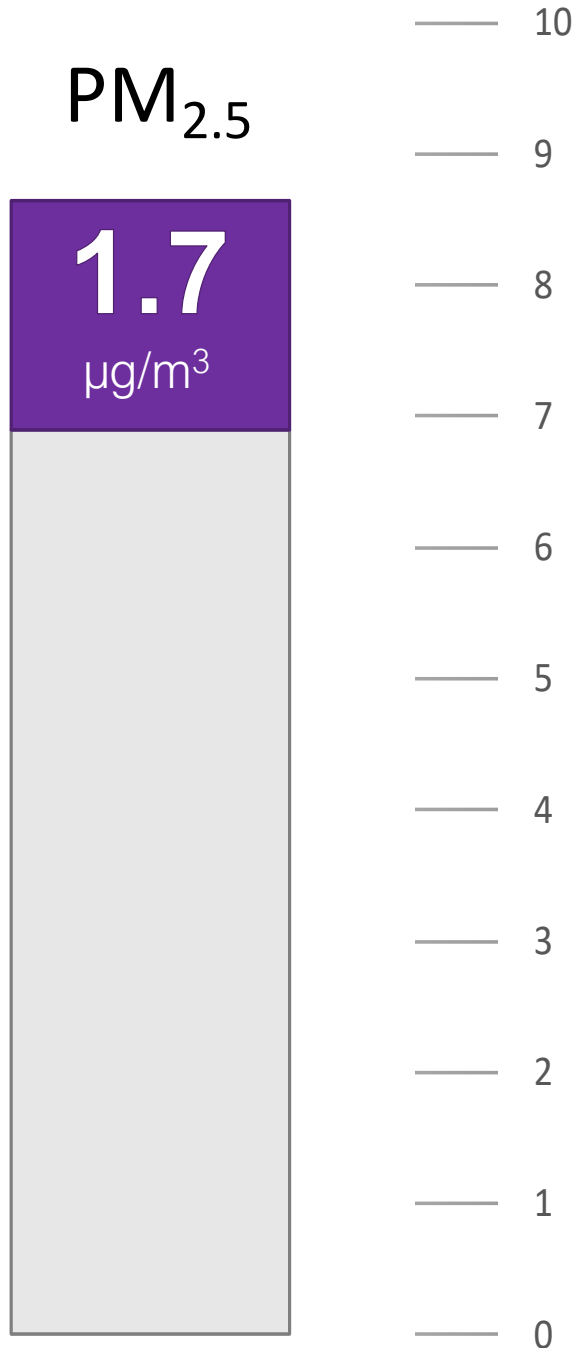
BAY AREA AIR QUALITY
MANAGEMENT DISTRICT



West Oakland
Environmental
Indicators Project
know which way the wind blows

Extra Slides

How Much is Local?



Local vs. Regional

- Local model – mapped impacts*
- Regional model (minus West Oakland)

*Construction, residential woodburning, and restaurants not modeled

Thank you

Break



Particulate Matter: Spotlight on Health Protection



Advisory Council Discussion with Exposure and Risk Panel

Discussion Questions

What are major sources of PM in the Bay Area?

What PM levels exist in Bay Area? What health risks do they pose?

How much additional health benefit can be achieved?

How should we account for spatial scale of effects (i.e., regional versus local-scale impacts, including proximity to major sources)?

How should we determine which measures would most move public health needle?

Advisory Council Deliberation



Particulate Matter: Spotlight on Health Protection

Adjournment



Particulate Matter: Spotlight on Health Protection



Particulate Matter: Spotlight on Health Protection



Particulate Matter: Spotlight on Health Protection

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

December 9, 2019



**BAY AREA AIR QUALITY
MANAGEMENT DISTRICT**

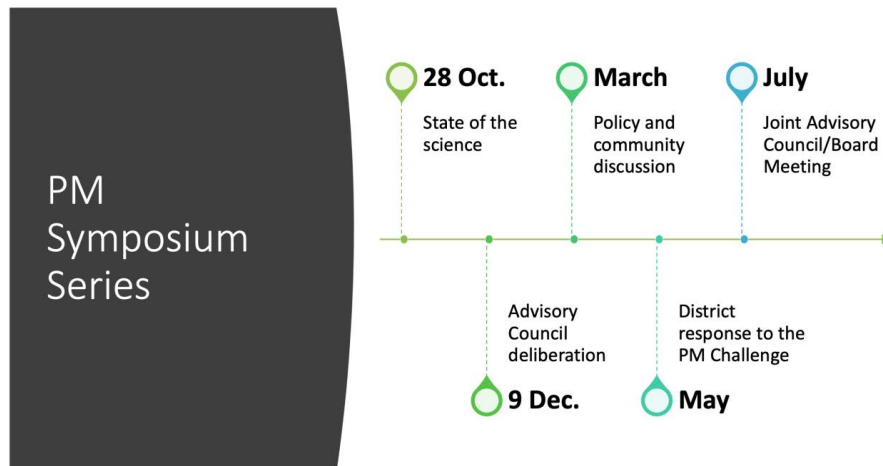
Table of Contents

Executive Summary.....	2
Background and Timeline	6
Update on Particulate Matter (PM) Air District Work: Regional- and Local-Scale PM_{2.5} Source Apportionment.....	8
Update on Particulate Matter (PM) Air District Work: Monitoring.....	12
Update on Particulate Matter (PM) Air District Work: Grants and Incentives	18
Update on Particulate Matter (PM) Work: CARB PM Research and Rules	23
Update on Particulate Matter (PM) Air District Work: PM Rules and Regulatory Development.....	27
Discussion of Draft October PM Symposium Report and Advisory Council Q&A Document	30
Public Comment.....	31
Next Steps	33
Appendix — Questions from Advisory Council and Air District sent to October PM Symposium Panelists	34

Executive Summary

The December 9, 2019 meeting of the Advisory Council (Council) of the Bay Area Air Quality Management District (Air District) focused on the Air District’s current and emerging work to understand, monitor, reduce, and control regional and localized particulate matter (PM) concentrations.

As the timeline below illustrates, this Advisory Council meeting followed the October PM Symposium, which focused on the state of the science, and preceded the upcoming March PM Symposium. The March PM Symposium will focus on local community work, needs, and priorities. The PM Symposium Series as a whole will inform recommendations from the Advisory Council to the Air District’s Board concerning further action the Air District can take to protect the health of Bay Area residents, particularly those who are disproportionately impacted by PM exposure.



[Note: At the time of the presentation, the PM Symposium Series was anticipated to continue through July; however, due to the COVID-19 pandemic and the Bay Area shelter-in-place order, this timeline has changed. Air District staff, together with the Advisory Council and community members, are continuing to discuss particulate matter reduction strategies.]

The December meeting featured presentations regarding local, regional, and state PM reduction initiatives from Air District staff members and a representative from the California Air Resources Board (CARB). Additional agenda items included Advisory Council discussion of a written report on the October PM Symposium; development of a new document by the Advisory Council, which will provide responses to the questions originally posed by the Advisory Council and the Air District to the October PM Symposium panelists; and public comment.

Presentations

Source Apportionment. Phil Martien, Director of Assessment, Inventory, and Modeling, presented the Air District's current knowledge and information gaps regarding the sources of fine particulate matter (PM) in the Bay Area (excluding wildfires). New priorities require the Air District and its partners (CARB, Caltrans) to evaluate and update source apportionment procedures and corresponding regulatory frameworks. As PM emissions from previously dominant sources (such as vehicle emissions) are reduced, additional sources emerge as priorities for controlling PM, yet less information is available about these newly emergent top sources. In particular, models for brake and tire wear and road dust have not been updated since the 1980s. Equally, the Air District's new focus on local-scale exposures requires new approaches to data collection, analysis, and rulemaking regarding stationary-source emissions. Point sources that are not significant at the regional level have not historically been prioritized for monitoring and control. These sources may be significant contributors of PM_{2.5} at the local level.

Monitoring. Ranyee Chiang, Director of Meteorology and Measurements, along with assistant managers Ila Perkins and Katherine Hoag, presented regarding the Air District's monitoring network. They discussed both region-wide monitoring — largely designed to track progress against national ambient air quality standards — and more recently deployed monitoring approaches that are designed to address the Air District's emerging focus on community-scale concentrations or impacts from specific sources of emissions. In response to the Advisory Council's requests, additional information was shared regarding ultrafine particles and wildfires. Ultrafine particle monitoring has been in place for several years but is limited in scope by costs and scientific limitations of the instrument. Wildfires have caused dramatic increases to PM_{2.5} concentration levels in the Bay Area, reversing a decade-long downward trend. The Air District is currently conducting an Integrated PM Network Assessment to evaluate its PM measurement network and recommend improvements.

Grants and Incentives. Karen Schkolnick, Director of Strategic Incentives, presented a summary of the Air District's grant revenue sources, current grants and incentive programs, and recent program results. Because these grant programs generally require emission reductions that go beyond regulatory requirements, the majority of the Air District's grant funding is targeted at reducing PM_{2.5}, other criteria pollutants, air toxics, and greenhouse gases from mobile sources and complementing the Air District's regulatory PM reduction strategies targeting stationary sources. She highlighted several key initiatives focused on reducing mobile-source emissions through adoption of the cleanest commercially available technology (such as Diesel Free by '33 and Port of Oakland partnerships) and discussed how these programs connect to other Air District priorities including health risk reduction in communities disproportionately impacted by air pollution. Since 1991, more than \$1.2 billion has been invested through the Air District's grants and incentives programs, resulting in significant emissions reductions and accelerated adoption of cleaner and zero-emission technology. However, each program is constrained by the requirements of its funding source — for example, only one of the Air District's sources of funding can be used to target vehicle miles traveled (VMT) reduction.

CARB PM Research and Rules. Alvaro Alvarado, Manager of Health & Ecosystems Assessment for CARB, described the PM research currently being conducted at CARB and the emerging regulations designed to further decrease PM emissions. In line with the Advisory Council's requests, he focused on research concerning wildfires, brake and tire wear, and ultrafine particles. Wildfire research includes study of a monkey colony at UC Davis, mobile platforms to monitor in-home exposures, and collaboration with NASA to track wildfires using aircraft. Brake and tire wear research includes laboratory studies to quantify emissions as well as exposure studies with UC Riverside and health effects studies with UCLA. Studies of ultrafine particles include modeling annual average concentrations and speciation throughout the state and associating mortality with long-term exposures using the California Teachers Study cohort. With respect to rulemaking, several regulations are underway or forthcoming to reduce emissions from trucks, cars, and trains.

Air District PM Rules and Regulatory Development. Victor Douglas, Manager of Rule Development, presented a brief overview of the history, current efforts, and emerging directions for rule development in the Air District, which continues to update its rules and regulations to further limit PM exposures. As its focus shifts from an exclusively regional perspective to reducing risks for disproportionately impacted local communities, the Air District is exploring further regulation regarding restaurants, wood smoke, and indirect or magnet sources (e.g. warehouses), as well as the possibility of treating PM as a toxic air contaminant. Although the State of California does not presently recognize undifferentiated PM as an air toxic, it may be possible for the Air District to do so independently.

Discussion of Draft October PM Symposium Report

The Advisory Council discussed the draft report on the October PM Symposium prepared by consulting technical writer Elisabeth Andrews on behalf of the Air District, available online at <https://www.baaqmd.gov/news-and-events/conferences/pm-conference>. Three clarifying edits were made to the section on "Advisory Council Deliberation," and consensus was reached on releasing the draft report for public comment.

Advisory Council Q&A Document

Advisory Council Chair Stan Hayes introduced a document he initiated that provides responses to the questions originally posed by the Advisory Council and the Air District to the October PM Symposium panelists concerning PM health effects, exposures, and risks. His aim was to distill the information shared by the panelists into concise answers to each of the questions. Council Member Gina Solomon volunteered to assist Chair Hayes in further developing the question-and-answer document.

Public Comment

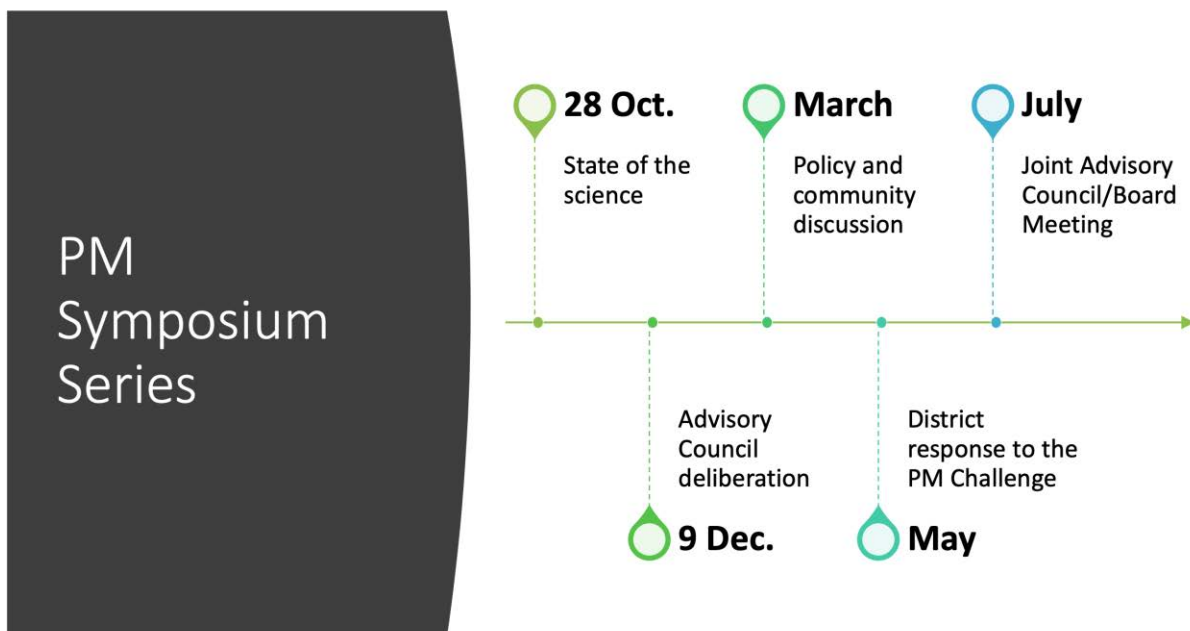
Commenters focused on the urgency of decreasing PM exposures and articulated a need to phase out fossil fuels and transition to a zero-carbon economy. Specific suggestions for the Air District included setting PM threshold levels based on sensitive subgroups rather than population averages, utilizing data from low-cost sensors and the California Household Exposure Study, and developing messaging campaigns focused on demonstrating the connection between specific sources of air pollution and health outcomes.

Next Steps

The next PM symposium will take place on March 24, 2020 in Oakland and is focused on presentations from community organizations and leaders. The May event is expected to focus on formulating potential Air District plans to further reduce Bay Area health risks from PM. The final event in the series brings together the Advisory Council and the Air District's Board of Directors to discuss the information and suggestions shared throughout the PM Symposium Series. During the July meeting, the Advisory Council is expected to present its findings to the Air District's Board of Directors regarding particulate matter and health in the Bay Area.

Background and Timeline

The December 9, 2019 meeting of the Advisory Council (Council) of the Bay Area Air Quality Management District (Air District) followed the October PM Symposium with updates on the Air District's current work on particulate matter (PM). Recognizing that PM is the overwhelming driver of health risks from Bay Area air quality, the Advisory Council requested that the Air District convene the PM Symposium Series in order to clarify the state of the science (October 28, 2019), describe current and forthcoming Air District work (December 9, 2019); learn about local community efforts, needs, and priorities (March 24, 2020); and present potential policy strategies (May 2020). As the timeline below illustrates, the series will culminate in recommendations from the Advisory Council to the Air District's Board of Directors concerning further action the Air District can take to protect the health of Bay Area residents, particularly those who are disproportionately impacted by PM exposure. An additional goal of the Air District and Advisory Council is to provide national leadership on improving air quality at a time when the federal government is retreating from this mission.



[Note: At the time of the presentation, the PM Symposium Series was anticipated to continue through July; however, due to the COVID-19 pandemic and the Bay Area shelter-in-place order, this timeline has changed. Air District staff, together with the Advisory Council and community members, are continuing to discuss particulate matter reduction strategies.]

The first symposium took place on October 28, 2019, convening national, state, and local experts to discuss the state of the science on PM health effects, exposures, and impacts. Details on the presenters and the information they shared can be found in the Draft October PM Symposium Report available at <https://www.baaqmd.gov/news-and-events/conferences/pm-conference>. Following that event, Chair Hayes presented to the Air District Executive

Committee of the Board of Directors on November 6, 2019 and to its full Board of Directors on November 20, 2019 concerning the Advisory Council's takeaways from the October PM Symposium.

Chair Hayes summarized those presentations at the December meeting. He highlighted several key topics discussed at the October PM Symposium: new evidence of causal relationships between PM and adverse health outcomes including premature death, evidence that the health of children and non-white people are disproportionately harmed by PM, strategies for understanding the sources and distribution of PM, and associations between wildfires and both respiratory and cardiovascular illness. He shared the Sense of the Advisory Council statement that emerged from deliberation at the close of the October PM Symposium:

The current standards are not adequately health protective.
Further reductions in PM will realize significant additional health benefits.
We need more science, *and* we should act now.

Chair Hayes also listed the topics the Advisory Council sought to explore further: approaching PM as an air toxic, expanding monitoring of ultrafine particles, examining health effects of acute PM exposures (e.g. wildfire smoke), identifying PM species that are particularly dangerous, assisting the Air District in identifying strategies with the "highest bang for the buck" in terms of health protection, and pursuing strategies that have climate and other co-benefits.

These priorities set the agenda for the December meeting, which focused on the Air District's current and emerging work to understand, monitor, reduce, and control regional and localized PM concentrations. A representative from the California Air Resources Board (CARB) also presented on state-level PM research and regulations. Additional agenda items included Advisory Council discussion of a written report on the October PM Symposium as well as public comment.

The meeting was shared live via webcast, the video archive of which can be viewed at http://baha.granicus.com/MediaPlayer.php?clip_id=6369.

Update on Particulate Matter (PM) Air District Work: Regional- and Local-Scale PM_{2.5} Source Apportionment

Phil Martien

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

<i>Main takeaway</i>	New priorities require the Air District and its partners (CARB, Caltrans) to evaluate and update source apportionment procedures and corresponding regulatory frameworks. As PM emissions from previously dominant sources are reduced, additional sources emerge as priorities for controlling PM, yet less information is available about these newly emergent top sources. This is particularly true for brake and tire wear and re-entrained road dust. Equally, the Air District’s new focus on local-scale exposures requires new approaches to data collection, analysis, and rulemaking regarding stationary-source emissions.
----------------------	---

Dr. Martien presented the Air District’s current knowledge and information gaps regarding the sources of fine particulate matter in the Bay Area (excluding wildfires). He first described how sources contribute to PM_{2.5} concentration levels at the regional level and then turned to the Air District’s community-scale analysis of local sources of PM_{2.5} for West Oakland. The report provided here reflects both the presentation from Dr. Martien and the additional comments and clarifications from other Air District staff members during the presentation.

Current Air District Work

Proportion of regional vs local contributions. Regional sources are the main driver of Bay Area PM_{2.5} concentrations: in West Oakland, local sources appear to contribute about 20% of the overall PM_{2.5} burden in the community. However, time constraints on the West Oakland analysis precluded modeling approximately 30% of local PM_{2.5} sources including construction, residential wood burning, and commercial cooking; these sources may constitute an additional proportion of local contribution to PM_{2.5} concentration levels. Moreover, local sources may have highly significant impacts for people living or working in the immediate vicinity of those sources.

Regional Scale Apportionment

Based on newly updated modeling, peak levels of annual-average PM_{2.5} in the Bay Area are on the order of 10 micrograms per cubic meter (µg/m³). In Air District modeling the highest values are seen in the Central Valley. It now appears that **secondary PM formation contributes almost half of PM_{2.5}**, which is higher than earlier estimates.

Sources of PRIMARY PM_{2.5} in the Bay Area:

- **Permitted sources (23%)** - Within this category, refineries produce more than 40% of emissions from permitted sources. The top five emitters contribute approximately half of all PM_{2.5} from permitted facilities.
- **On-road mobile sources (27%)** - Within this category, vehicle exhaust now contributes less than 20% of on-road mobile emissions. Brake and tire wear and road dust are far more significant contributors.
- **Non-road mobile sources (16%)** - Within this category, construction activity and commercial marine vessels each account for approximately one third of emissions from non-road mobile sources.
- **Area sources (34%)** - These sources tend to be individually small emitters that collectively make up a large portion of PM_{2.5} emissions, including residential wood combustion and commercial cooking (largely char-broilers).

Sources of SECONDARY PM_{2.5} in the Bay Area:

- **Diesel** trucks and off-road equipment contribute **NO_x**
- **Stationary sources** (including refineries and manufacturing plants) contribute **SO₂**
- **Agricultural activity** contributes **NH₃**

Community Scale Apportionment

Hyperlocal analysis of local-source primary PM_{2.5} emissions was conducted for West Oakland, as described in the report on the October PM Symposium (<https://www.baaqmd.gov/news-and-events/conferences/pm-conference>) and the [West Oakland Community Action Plan](#). Annual averages of PM_{2.5} concentrations exclusively from local sources were calculated for each census block. PM_{2.5} concentration levels were observed to vary seasonally, across the week, and even hour-by-hour with local activity.

Roadways and permitted facilities. Roadways and permitted facilities emerged as predominant local sources of primary PM_{2.5} in West Oakland (acknowledging again that time constraints precluded modeling construction, residential wood burning, and commercial cooking).

Hyperlocal variation in source apportionment. Predominant sources of local-source PM_{2.5} vary within West Oakland: in its southwest corner, the contributions of port and rail to local-source PM_{2.5} are as high as 25%; roadway contributions in some locations are more than 75%; in other locations stationary sources contribute on the order of 40% of local-source PM_{2.5}.

Unequal impacts. Certain census blocks in West Oakland are exposed to much higher levels of local-source PM_{2.5} than others.

Forthcoming Air District Work

The Air District faces challenges in overcoming information gaps concerning newly dominant sources of PM_{2.5}. As PM emissions from top sources are reduced, additional sources emerge as priorities, yet less information is available about these other sources. As a result of this lag between re-prioritization and updated scientific literature, there is considerable uncertainty in the estimates of source apportionment, and this uncertainty cannot yet be quantified.

Road dust. As emissions from vehicle exhaust are reduced, the proportion of PM_{2.5} attributed to re-entrained road dust increases. However, calculations for re-entrained road dust were last updated in the late 1980s. These methods are being currently evaluated and updated by CARB and Caltrans.

More analysis of permitted sources. Point sources that are likely significant contributors of PM_{2.5} at the local level may not be significant at the regional level. Because the Air District's focus has historically been at the regional level, direct measurements have not been collected for most of these sources. For example, because West Oakland permitted facilities account for only about 0.5% of emissions in the Bay Area, they have not historically been prioritized for monitoring and control. The Air District's new focus on localized impacts demands greater attention to these sources. For other Bay Area locations, particularly those in which the top five stationary-source emitters are located, the Air District is also in the process of determining local-scale impacts for residents. It is not yet clear how much exposure people experience from these emissions, particularly where emissions are distributed through tall stacks.

Post-Presentation Discussion

Brake and Tire Wear and Road Dust

- Council Member Linda Rudolph inquired about the **climate impacts** of newly emerging PM_{2.5} priorities such as brake and tire wear and road dust. Dr. Martien responded that different PM_{2.5} species can have different climate effects: soot tends to be warming, whereas secondary aerosol can be cooling. Air District Deputy Air Pollution Control Officer Greg Nudd added that road dust tends to be a localized issue as concentrations drop off quickly in spatial terms. However, brake and tire wear have emerged as water quality issues: microplastics in the San Francisco Bay have been shown to originate from tire wear.
- Council Member Severin Borenstein inquired about **technologies to reduce these effects**; Mr. Nudd and Air District Deputy Air Pollution Control Officer Damien Breen responded that reduction in vehicle miles traveled (VMT) is the primary control strategy as few technologies have emerged apart from vacuuming highways and some new European experiments in under-vehicle misting technologies. He later remarked that successful strategies for reducing road dust involve reducing the load on the road; while sweeping can have some positive effect, reducing track-out from construction and limiting roadside contributions through landscaping or paving tend to be more successful.

- Chair Hayes confirmed with Dr. Martien that brake and tire wear and road dust contribute significantly to both local and regional PM_{2.5} exposures and remarked that addressing this issue will be an **important issue for the Air District**.
- Council Member Borenstein inquired about the **relationship between speed, congestion, and PM_{2.5}**. Mr. Breen explained that less speed generally means higher exhaust emissions; Dr. Martien stated that dynamometer testing is currently investigating the relationship between speed and brake wear for light- and heavy-duty vehicles.

Air toxics approach. Council Member Michael Kleinman suggested that the greatest benefit to public health may be gained through focusing on the most toxic components of PM_{2.5}. He provided the example of lead-contaminated particles from the cement plant in Cupertino posing more of a public health threat than ammonium sulfate aerosols (from secondary PM_{2.5} formation) and stated that many of the secondary aerosols in PM_{2.5} are less toxic than the primary aerosols.

Challenges with commercial cooking and residential wood burning. Council Member Solomon inquired about the Air District's authority with respect to commercial cooking, noting that the categories of regionally significant sources of PM_{2.5} that are within the Air District's jurisdiction appear to make up 43% of the total regional apportionment. Mr. Nudd, with confirmation from Air District Legal Counsel Brian Bunger, explained that the Air District's regulatory authority for commercial cooking is clear. The Air District has an existing rule for large charbroilers. However, available post-combustion controls for restaurant cooking are too large to fit on a restaurant roof and too expensive to preserve profit margins. With respect to reducing residential wood burning, the challenge lies in overcoming cultural barriers.

Update on Particulate Matter (PM) Air District Work: Monitoring

Ranyee Chiang

Director, Meteorology & Measurements, Bay Area Air Quality Management District

Ila Perkins

Assistant Manager, Meteorology & Measurements, Bay Area Air Quality Management District

Katherine Hoag

Assistant Manager, Meteorology & Measurements, Bay Area Air Quality Management District

<i>Main takeaway</i>	The Air District’s new focus on community-scale monitoring complements its ongoing region-wide monitoring efforts. UFP monitoring has been in place for several years but remains limited in scope by costs and scientific limitations of the instruments. Wildfires have caused dramatic increases to PM_{2.5} concentration levels in the Bay Area, reversing a decade-long downward trend.
----------------------	--

Dr. Chiang presented along with two assistant managers in Meteorology & Measurements, Ms. Perkins and Dr. Hoag, on the Air District’s current monitoring network. They discussed both region-wide monitoring — largely designed to track progress against national ambient air quality standards — and more recently deployed monitoring approaches that are designed to address the Air District’s emerging focus on community-scale concentrations or impacts from specific sources of emissions. In response to the Advisory Council’s requests, additional information was shared regarding ultrafine particles and wildfires.

Current Air District Work

Regional/Regulatory Network

The Air District currently has 35 fixed air monitoring stations (as well as 20 meteorology stations) that provide timely air quality data to the public, compare PM concentration levels with national and state standards, inform air quality forecasts for the Spare the Air program, and support research studies. Most sites are selected based on the distribution of the population (2010 Census) and the concentration of pollutants, with some additional sites placed downwind of major pollution sources, to describe regional transport of pollutants, or in areas representing general background PM levels.

The measurement instrumentation used for Air District PM monitoring is described in Table 1. Mass measurements support compliance with California and national PM₁₀ and PM_{2.5} health-based standards and designate which areas are in attainment or nonattainment; chemically

resolved or speciated data measurements support emission reduction strategies; and particle counts of smaller particle sizes support science on emissions, air quality impacts, and health effects of types of PM for which there is currently no health-based standard.

Table 1 - Air District PM Instrumentation

Measurement Type	Mass		Chemically resolved or speciated		Particle count
Measurement application	Compliance with standards; Designate areas as attainment or nonattainment		Support emission reduction strategies		Assess air quality impacts and exposures
Analytical Target	PM ₁₀ mass	PM _{2.5} mass	Black carbon	PM _{2.5} speciation	Ultrafine particles (PM _{0.1})
Analytical Methods	Gravimetric	Gravimetric or Filter-based beta attenuation	Filter-based light attenuation	Chemical extraction	Laser-based
Number of Active Monitors	7	20	7	4	6

Ultrafine Particle Monitoring

Strengths. The Air District has conducted ultrafine particle monitoring for more than seven years in a range of sites, producing data that can be used to understand diurnal and seasonal patterns and trends as well as differences between background, near-road, and typical urban settings.

Limitations. Ultrafine particle instrumentation is costly (\$60,000-\$100,000 per unit), requires frequent maintenance in PM-burdened areas, and cannot presently support identification of sources and sinks or robust links to specific health impacts.

Results. Air District ultrafine particle monitors installed in a variety of locations reveal that UFP concentrations reflect fresh, primary particulate emissions from both combustion and secondary formation. Higher levels of ultrafine particles are seen in near-road environments, with peaks at high-commute hours and the middle of the day, indicating a photochemical signature.

Wildfires

Prior to 2017, occasional impacts from wildfires did not have a significant influence on year-to-year trends, yet recent wildfires have dramatically affected Bay Area PM_{2.5} concentration levels. Figure 1 shows the overwhelming effect of wildfires in 2017 and 2018. With wildfire days

removed, there has been a downward trend in PM_{2.5} concentration levels for the past decade, yet wildfires have caused a sharp reversal of that trend, resulting in the Bay Area substantially exceeding the 24-hour federal standard for 2016 – 2018.

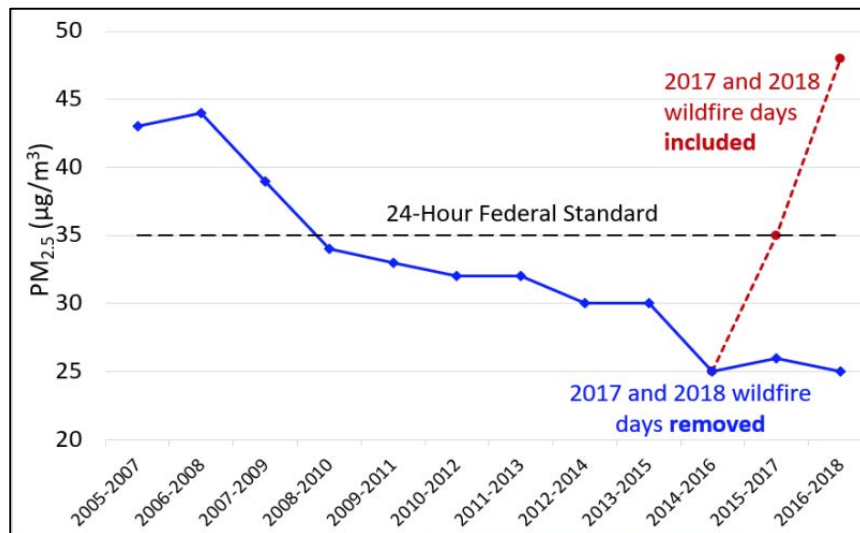


Figure 1 - Wildfire impact on 24-hour PM_{2.5} concentration levels

Air District initiatives to minimize exposure to wildfire PM include:

- Communicating with the public about reducing personal exposure
- Collaborating with public health officers and other agencies to ensure consistent messaging
- Funding Clean Air Centers in which vulnerable people can seek refuge
- Offering grants and incentives for recovery assistance
- Providing guidance for local organizations, particularly schools

Forthcoming Air District Work

Community-Scale Monitoring

Several new developments support the Air District’s new focus on community-scale monitoring:

Hyperlocal monitoring

In partnership with [Aclima](#), the Air District is conducting street-by-street monitoring using vehicle-mounted sensor-based instrumentation measuring NO_x, CO, O₃, and PM_{2.5}, similar to previous studies Aclima performed in West Oakland and other areas. Measurements for a short-term study in the AB 617 Richmond-San Pablo study area will soon be available, and the Air District aims to use this technology to map average baseline hyperlocal air quality for the entire Bay Area within two years.

Mobile Laboratories

The Air District is also developing a van with mobile monitoring capabilities that can perform high-accuracy, detailed mobile or short-term measurements of PM and many specific gaseous air toxics, including the amount of PM of different sizes. Potential uses of this new monitoring van include supporting localized source apportionment and prioritization, confirming and improving the understanding of air quality issues identified by the AB 617 Steering Committees, and identifying locations for further fixed-site or portable monitoring.

Portable platforms

Highly portable, suitcase-sized monitoring systems will also be developed for battery-powered, continuous, real-time PM measurements. Although these technologies are expensive, they could enable measurements during power outages, which is important for supplying real-time air quality data during wildfires and periods of heightened wildfire hazard. These instruments can also be used to verify data from lower-cost sensor networks (such as [PurpleAir](#)).

Combining Monitoring Strategies

Whereas the regional fixed site network is primarily focused on large-scale assessments and long-term trends, the special projects and sensor networks described in Table 2 enable more community-specific assessment. The Air District’s engagement in sensor networks involves working closely with community organizations and companies to provide technical capacity building and advice regarding the advantages, limitations, and uncertainties of different technologies.

Table 2 – Air District PM Monitoring Strategies and Objectives

Network	Measurements	Objectives	Limitations
Regional Network	PM _{2.5} and PM ₁₀ mass	-Comparison with standards -Public information -Track long-term trends -Assess out-of-area transport	-High cost -Information gaps at community scale
Special projects: -fixed site -mobile laboratory -portable platforms	-PM size distribution -PM speciation -Ultrafine particles -Black carbon	-Source identification -Assessment of specific emission sources -Characterization of near-road environments	-High cost
Sensor networks: -fixed site -mobile/portable	-PM mass -Particle count	-Public education -Personal exposure monitoring -Identification of hot spots -Comparative assessment of local air quality -Tracking high-PM episodes	-Higher level of uncertainty

To strengthen these approaches, the Air District will complete an **Integrated PM Network Assessment by July 2020** to evaluate its PM measurement network and recommend

improvements. The assessment aims to determine how available resources and multiple monitoring approaches can best be deployed not only to continue addressing federal and state requirements but also to support and expand community-scale air monitoring activities and other Air District programs.

Post-Presentation Discussion

Ultrafine Particles

- **Monitoring costs.** Council Member Solomon inquired whether ultrafine particles monitoring equipment costs are expected to drop in the foreseeable future. Ms. Perkins replied that the Air District relies on one primary manufacturer and does not anticipate near-term cost reductions. Council Member Solomon introduced the idea of a challenge to technology developers to accelerate innovation in the direction of affordability. Dr. Chiang responded that she would contact representatives from the Environmental Protection Agency and CARB to investigate the possibility of pooling resources to propose such an initiative.
- **Data application.** Council Member Rudolph asked how the Air District’s ultrafine particle data is being used to improve public health. Dr. Hoag responded that the data adds to the imperative to reduce roadway emissions. Mr. Nudd added that the Air District is implementing project grants to install filtration in near-roadway schools and is advising the Plan Bay Area initiative on limiting near-roadway exposures.
- **“We need more science, and we should act.”** Chair Hayes reiterated the message from the first PM Symposium that while it is clear that more science is needed on UFP — including a federal reference method standardizing ultrafine particle measurement and epidemiological studies linking exposures to health effects — the Air District should also take immediate action.
- **Near-road health effects.** Following clarifications from Air District staff that the high levels of monitored UFP were due to roadway proximity, Council Member Kleinman pointed out that the documented health effects of near-road environments include low birth weight and cardiovascular problems. While there are many challenges for ultrafine particle research, including the difficulty of assessing dosage due to the extraordinarily low mass of UFP, studying the health effects of near-road environments may be an effective approach to understanding UFP exposures. He added that ultrafine particle concentrations drop precipitously as the distance from the roadway increases, with particle counts dropping by 80% at a 100-meter distance from the center of the road (and an additional 80% at a further 100 meters). Therefore, zoning regulations, berms, and buffers can make a significant difference in limiting exposures.
- **Combustion as source of UFP.** Dr. Hoag clarified in response to Council Member Borenstein’s question about brake and tire wear and road dust that the source of UFP is combustion, not vehicle wear or road dust. She further clarified in response to Council Member Tim Lipman’s question about ultrafine particle precursors that the sources of UFP appear to be anthropogenic.

- **Stationary sources and UFP.** Council Member Solomon asked whether the Air District has investigated UFP emissions from stationary sources. Dr. Hoag responded that such analysis has not been conducted, in part because UFP concentrations are unlikely to remain high outside the perimeter of the facilities due to the distance-based decreases in particle counts described above. However, she stated that this type of measurement could be a possible application for the new mobile and portable monitoring technologies.
- **UFP gradient studies in the Bay Area.** Council Member Solomon asked whether the Air District is conducting studies to assess the persistence of UFP concentrations at increasing distances from Bay Area roadways. Dr. Hoag replied that this analysis had not been undertaken as part of UFP monitoring in the Bay Area but that many previous studies had established the patterns of near-roadway UFP distribution, including the influence of meteorology, topography, and roadway design.

Data sharing. Council Member Rudolph also asked for clarification on how data is being shared with the public. Mr. Breen stated that regional network monitoring data is available on the Air District website (<http://www.baaqmd.gov/about-air-quality/current-air-quality>). Dr. Hoag added that the community-scale data being collected by Aclima will also be publicly available once it has undergone quality assurance.

Update on Particulate Matter (PM) Air District Work: Grants and Incentives

Karen Schkolnick

Director, Strategic Incentives, Bay Area Air Quality Management District

<i>Main takeaway</i>	Since 1991, more than \$1.2 billion has been invested through the Air District’s grants and incentives programs, resulting in significant emissions reductions and accelerated adoption of cleaner and zero-emission technology. Because these initiatives are not subject to regulatory constraints, the Air District is able to use the great majority of funds to target mobile sources. However, programs are constrained by the requirements of the funder — for example, there is only one source of funding that can be used for VMT reduction.
----------------------	---

Ms. Schkolnick presented a summary of the Air District’s grant revenue sources, current grants and incentive programs, and recent program results. She highlighted several key initiatives that incentivize the accelerated adoption of the cleanest commercially available technology and discussed how these programs connect to other Air District priorities including health risk reduction in communities disproportionately impacted by air pollution.

Current Air District Work

Prioritization Process

Because grants and incentive programs are not tied to regulatory constraints, the Air District is able focus almost all of its funding through these programs (90 to 95%) on reducing mobile-source emissions. Most of this funding goes toward accelerating the adoption of the cleanest commercially available technology. An additional priority is expediting emissions reductions in disproportionately impacted communities.

The cost effectiveness (CE) of nearly all programs is evaluated using the following formula (or a variant) from the Carl Moyer Program, established by the State of California and CARB:

$$CE = \frac{\text{Funds Awarded}}{\text{Tons of } NOx + ROG + (PM_{10} \times 20) \text{ reduced}}$$

Notably, this formula has changed over 20 years by incrementally increasing the weighting of PM from 1 to 20, reflecting the State’s interest in health protection.

Current Funding Allocation

\$97 million from grants and incentives in 2018 were allocated to:

- **On-road emissions reduction — \$32 million (one third)**, supporting both deployment and infrastructure for lower- or zero-emission light-, medium-, and heavy-duty vehicles (cars, trucks, and buses). Notably, pass-through programs also support this category, so the total amount of support is higher than this number.
- **Off-road mobile source emissions — \$44.4 million (almost half)**, from sources such as cargo handling equipment, agricultural equipment, marine and locomotive vehicles, and airport ground support. These are primarily diesel emissions and the cleanest commercially available technology in most cases is cleaner diesel, transitioning from Tier 0 or 1 to Tier 4 engines, although some electrification is now occurring such as Caltrain and lighter cargo handling and air ground-support equipment.
- **Vehicle Miles Traveled (VMT) reduction — \$6.2 million (plus nearly \$9 million in pass-through)**, including shuttle and ride-share services connecting to mass transit, pilot services such as Bay Area Bike Share (now sponsored by Lyft), and expansion of bikeways and bike parking. The Spare the Air program is also funded in this category. For the Spare the Air program, funding is also supplied through pass-through programs, so the total amount of support is higher.
- **Household technology and local climate action — \$5.1 million**, including lawn and garden equipment replacement, wood smoke reduction (now focused on reducing combustion through transition to heat pumps), and capacity-building for schools and local government.
- **Pass-through to county transportation agencies — \$9.5 million**, primarily to implement trip reduction and on-road vehicle emissions reduction.

Notable Initiatives

Diesel Free by '33

This program focuses on introducing zero-emission technology in each category of vehicles and equipment as soon as it becomes commercially available. While the present focus is on the light-duty sector, the program is designed to incorporate categories such as marine, locomotive, and construction vehicles and equipment as technology evolves.

The **light-duty sector** demonstrates the expected pattern: While hybrid and natural gas vehicles were the best available technology 10 years ago, zero-emission vehicles have since emerged and become a focus for Air District grants and incentives funding. Currently:

- More than \$15 million has been invested by the Air District, plus additional investments from the federal and state government and the private sector to help accelerate the adoption of light-duty zero-emissions vehicles
- Almost 8,000 electric vehicle charging ports are in place

- Renewables are included in 25% of Air District-supported charging ports
- Low-income residents are a focus for vehicle electrification programs
- 3% of Bay Area vehicles are electric
- 25% of all electric vehicles in the U.S. are in the Bay Area
- Goal: Five million vehicles by 2050
 - Presently ahead of schedule
 - Limitation is availability of vehicles

R&D advanced technology demonstration programs

The Air District also participates in advanced demonstration programs, which provide proof-of-concept for the deployment of improved technologies that are not yet commercially available. The Air District has recently been serving as the lead administrator for a \$2.9 million project in partnership with Goodwill Industries, BYD (a manufacturer of heavy-duty battery electric vehicles and equipment) and CARB. This project will test and deploy 10 electric delivery trucks and one refuse hauler. Another \$3 million project in partnership with Golden Gate Zero Emissions Marine and CARB will build, test, and deploy the first hydrogen-powered ferry for passenger service in mid-2020. Both of these projects are funded primarily through the California Climate Investments program from CARB's Low Carbon Transportation program.

Port of Oakland

Over the course of ten years, Air District grants have invested approximately \$120 million in retrofitting and replacing vehicle technology and infrastructure at the Port of Oakland, including replacing approximately 2,000 drayage trucks and more than 1,000 on-road trucks, installing shore power at 14 berths, and updating harbor craft and cargo handling equipment.

Recent (since 2015) Results and Highlights

Significant reductions in regionwide emissions

- CO₂: nearly 600K tons
- NO_x: more than 3K tons
- Reactive organic gas: more than 1K tons
- PM₁₀: nearly 400 tons

Infrastructure and equipment implemented

- More than 1,000 electric vehicle charging stations
- Approximately 40 miles of bikeways
- More than 1,200 woodstoves and fireplaces replaced
- More than 100 zero-emissions transit and school buses

Supporting disproportionately impacted communities

Approximately 53% of funds went to programs in Community Air Risk Evaluation (CARE) areas.

More than \$1.2 billion in total investments

Through 2020, clean air investments from Air District grants and incentives total over \$1.2 billion. This figure represents significant growth since these programs were initiated in 1991 with approximately \$5 million.

Forthcoming Air District Work

For 2020, an estimated \$108 million will be invested through the Air District's Strategic Incentives programs. In addition to the continuation of the initiatives described above, including the expansion of eligible vehicles and equipment for Diesel Free by '33, the Air District will promote:

- expansion of **lawn and garden** equipment replacement programs,
- reducing **motorcycle** usage,
- funding **air filtration systems** and **clean air shelters**,
- funding **climate resilience** programs, and
- securing **new sources of funding** to expand eligibility of existing programs (such as VMT reduction) and initiate new efforts.

Post-Presentation Discussion

Successes. Chair Hayes and Council Member Rudolph commended the Air District's successes through its grants and incentives programs, particularly with regard to the Port of Oakland and other initiatives targeting diesel particulate matter.

VMT reduction. Council Member Rudolph asked why more funding had not been allocated to VMT reduction and inquired whether the Carl Moyer formula disincentivized VMT as a focus. Ms. Schkolnick explained that while VMT reduction is a priority for the Air District, efforts are limited by available funding sources. The only funding stream that allows for VMT reduction is the Transportation Fund for Clean Air. Annually, of that fund's approximately \$25 million, \$9 million is allocated as a pass-through to county transportation agencies and used primarily for VMT reduction. The Air District's remaining amount from that fund is split between light-duty emission reduction programs and reducing VMT. Additionally, the Air District partners with the Metropolitan Transportation Commission on regional efforts such as the [Bay Area Carpool Program](#) through 511.org and Spare the Air. Mr. Breen added that the new focus on VMT and reducing brake and tire wear and road dust comes as a result of the Air District's successes in reducing emissions from diesel particulate matter, which was previously the predominant source of PM and remains a significant health concern in disproportionately impacted communities. He noted that the science has not yet caught up to the change in priorities, and that the Air District can advocate for changes in legislation once that science is clear.

Retirement of diesel equipment. Council Member Lipman inquired whether the Diesel Free by '33 initiative is retiring diesel vehicles and equipment or only adding additional lower- and zero-emissions technologies to fleets. Ms. Schkolnick clarified that nearly all Diesel Free by '33 programs are replacement programs.

Evaluation formula. Chair Hayes asked for clarification on the use of the Carl Moyer guidelines for evaluating cost effectiveness. In response to Chair Hayes' question concerning the designation of PM₁₀ as the focus of emissions reduction, Ms. Schkolnick affirmed that the formula does specify PM₁₀ rather than PM_{2.5}. She added that there has been some discussion about converting the formula to PM_{2.5}, but it is not clear how the formula would need to be altered to result in an equivalent evaluation. She also clarified in response to Chair Hayes' question about sidebar calculations that the Air District does use additional and more complex calculations to further evaluate some programs, such as co-benefits, PM_{2.5}, brake and tire wear and road dust, and proximity to disproportionately impacted communities. Council Member Kleinman commented that the risk of specifying PM₁₀ is that coarser particles are easiest to remove and, due to their greater mass, will reflect a greater apparent reduction of emissions while potentially leaving in place all the PM_{2.5}. He noted that to ensure health protection it would be beneficial to apply an alternative formula that balances that risk. Mr. Breen clarified that while the Carl Moyer Program requires the application of the specified formula, the tools that the Air District uses (such as calculating Significant Emissions Rates and using diesel particulate matter filters) do capture PM_{2.5}. He acknowledged that the more difficult correlation to establish is the degree to which applying the Carl Moyer guidelines using Air District approaches succeeds in reducing ultrafine PM.

Renewable charging stations. Council Member Kleinman asked how many of the approximately 8,000 electrical vehicle charging stations use renewable energy. Ms. Schkolnick replied that while she did not have information about all of the charging stations in the area, approximately 25% of the stations that the Air District has funded use renewable energy (primary solar).

Update on Particulate Matter (PM) Work: CARB PM Research and Rules

Alvaro Alvarado

Manager, Health & Ecosystems Assessment, California Air Resources Board (CARB)

<i>Main takeaway</i>	CARB is currently conducting research to better understand the air quality impact of wildfires, brake and tire wear, and ultrafine particles. New and forthcoming regulations will soon be implemented to further reduce emissions from mobile sources.
----------------------	--

Dr. Alvarado described the PM research currently being conducted at the California Air Resources Board and the emerging regulations designed to further decrease PM emissions. In line with the Advisory Council's requests, he focused on research concerning wildfires, brake and tire wear, and ultrafine particles. Several regulations are underway or forthcoming regarding trucks, cars, and trains.

Current CARB Research

Why PM? Dr. Alvarado began his presentation by highlighting the health impacts of PM including approximately 7,200 premature deaths each year in California. Although CARB regulations specifically track hospitalizations and emergency room visits as health outcomes of PM, CARB is also aware of and concerned with outcomes such as asthma attacks and other respiratory symptoms, adverse brain effects, and work loss days. He noted that regulations implemented over the past 25 years, particularly with respect to trucks, have contributed to substantial decreases in average PM_{2.5} concentrations.

Wildfires

Millions of Californians — by some estimates, the entire State population — were exposed to wildfire smoke in 2018, and wildfires are expected to become more frequent and widespread as a result of climate change. Although the current assumption is that all PM is equally toxic, this may not be the case; as wildfires cause more extensive damage there will be more combustion of structures and vehicles that could cause more toxic smoke. Effects could be particularly pronounced for children and older adults. Current CARB research includes:

- **Monkey study at UC Davis.** As Office of Environmental Health Hazard (OEHHA) Director Lauren Zeise described during the first Air District PM symposium, UC Davis researchers are investigating the effects of the 2008 wildfires on an outdoor captive monkey colony. When compared to monkeys in the population born in 2009, monkeys that were infants in 2008 experienced impaired immune function, changes in lung structure, and reduced

lung function, which persisted into adulthood. Moreover, immune effects were passed on to the next generation.

- **Wildfire emissions research.** Researchers at UC Berkeley and UC Riverside are using mobile monitoring platforms to investigate in-home exposures to wildfire smoke, and CARB is partnering with NASA to use aircraft to collect wildfire data.

Brake and Tire Wear

As previously noted by other presenters, as tailpipe emissions are reduced, brake and tire wear become more predominant sources of mobile-source PM. These emissions are more localized; whereas tailpipe emissions are associated with secondary PM and downwind exposures, brake and tire wear primarily affect people living near roadways. Health effects from brake and tire wear may be distinct from tailpipe emissions due to the presence of metals and plastics in wear-based PM emissions. Current CARB research includes:

- **Laboratory studies** quantifying brake and tire wear emissions using dynamometers,
- **Community exposure** studies with UC Riverside, and
- **Health effects** studies with UCLA.

Ultrafine Particles

Dr. Alvarado reiterated that ultrafine particles are difficult to measure and study, that it travels from the lungs to other organs including the brain, and that concentrations vary by space and time with peaks near roadways and during traffic that taper off at a distance and at night. He noted that prior research, primarily in Europe, has limited utility as it tends to focus on short-term exposures (one to four days) measured at only one location and using the extreme outcomes of hospitalizations and premature death. If ultrafine particles are similar to PM_{2.5}, long-term exposures can be expected to be far more significant than short-term exposures and indexed to population proximity and vulnerability.

To begin closing these research gaps, current CARB research is 1) **modeling ultrafine particles** annual average concentrations and speciation throughout the state and 2) **associating mortality** with long-term exposures using the California Teachers Study cohort. Preliminary results suggest an increased risk of premature death with high exposure to ultrafine particles. Additionally, to better understand health effects of short-term exposures to UFP, CARB is working with Council Member Kleinman to identify gaps in available research and develop a research plan.

Forthcoming CARB Regulations

A number of regulations will soon be implemented to further reduce mobile source emissions.

Heavy-Duty Trucks

- Advanced Clean Truck Regulation will transition heavy-duty trucks to zero emissions starting in 2024.
- Heavy-duty vehicle inspection and maintenance will require trucks to pass an inspection similar to a smog check in order to register with the California Department of Motor Vehicles.
- Innovative Clean Transit will transition public transit buses to zero emissions.
- Airport shuttles will also be transitioned to zero-emission vehicles by 2035.
- The Heavy-Duty Low NO_x omnibus rule will reduce NO_x as well as PM from diesel trucks, thereby addressing both primary and secondary PM.

Warehouses

- CARB is developing a Freight Handbook outlining best practices for warehouses to reduce their contributions to emission levels.
- New regulations are being developed for:
 - Transport refrigeration units,
 - Drayage trucks, and
 - Cargo handling equipment.

Passenger Cars

- Advanced Clean Cars 2 will increase the number of zero-emission vehicles on the road and reduce tailpipe emission through 2026.
- Catalytic converter theft reduction is being implemented to ensure that converters are stamped by manufacturers and registered with cars.

Trains

CARB is currently working with railyards in southern California to reduce idling. Lessons from this effort will be applied statewide, potentially through regulation, to reduce emissions from trains.

Post-Presentation Discussion

Next steps? Chair Hayes asked for the presenter's opinion on the next steps to improve public health. Dr. Alvarado, who clarified that he was speaking on behalf of himself and not CARB, replied that his priority would be to utilize low-cost in-home monitors to better understand how short-term localized exposures are affecting people in disadvantaged communities. This information could be used to direct regulations and resources toward improving health among the most vulnerable Californians, in line with AB 617.

Addressing brake and tire wear and road dust. Noting that Dr. Martien’s presentation revealed that the great majority of PM emissions experienced in West Oakland are from regional sources, Chair Hayes inquired whether brake and tire wear and road dust contribute to these regional-source exposures and whether these issues are under CARB’s regulatory authority. Dr. Alvarado replied that he could not speak to CARB’s authority on these matters, but that brake and tire wear and road dust are more localized issues. Council Member Kleinman commented that regenerative braking technology appears to reduce brake wear and could be a useful target for incentive structures. Council Member Lipman clarified that such technology can only be used with hybrid vehicles, but that it could be promising as an innovation that benefits both fuel efficiency and PM reduction.

Relative health impact of wildfires. Chair Hayes asked the presenter to characterize the relative contribution of wildfires to public health risk in comparison to day-to-day PM emissions from other sources. Dr. Alvarado responded that while there was not sufficient research to quantify the impact of wildfires at their newly intensified levels, it does appear that wildfire smoke has health effects similar to those of other types of PM exposure.

Defining premature death. Council Member Lipman asked for clarification on how premature death is defined in CARB’s calculations. Dr. Alvarado, along with Council Members Kleinman and Rudolph, clarified that the calculation is a statistical analysis of population-level loss of life relative to life expectancy.

New technologies increasing UFP? Council Member Solomon recalled that when natural gas and diesel reduction technologies were first being developed for transportation, there was some concern that they could increase ultrafine particle emissions. She asked whether that prediction had been accurate. Dr. Alvarado responded that while he would need to check to be certain, he believed that an initial increase in ultrafine particles was seen in early natural gas vehicles, but the problem had since been addressed through controls.

Update on Particulate Matter (PM) Air District Work: PM Rules and Regulatory Development

Victor Douglas

Manager, Rule Development, Bay Area Air Quality Management District

<i>Main takeaway</i>	The Air District continues to update its rules and regulations to further limit PM exposures. As its focus shifts from an exclusively regional perspective to reducing risks for disproportionately impacted local communities, the Air District is exploring the possibility of treating PM as a toxic air contaminant. Although the State of California does not presently recognize undifferentiated PM as an air toxic, it may be possible for the Air District to do so independently.
----------------------	--

Mr. Douglas presented a brief overview of the history, current efforts, and emerging directions for rule development in the Air District. He described how the Air District's emerging focus on health risks for local communities is prompting further consideration of rulemaking regarding stationary source emissions and potential treatment of undifferentiated PM as an air toxic.

Current Air District Work

Approaches

The Air District has approached PM regulation in three distinct ways:

1. As a **nuisance**, which was the initial approach in the first Air District regulations adopted in 1979 and 1980 regarding open burning and dust and aerosols.
2. As a **criteria pollutant**, which is the current, regional approach to undifferentiated PM governing attainment of ambient air quality standards. These regulations apply to both primary PM (filterable and condensable) and precursors of secondary PM (oxides of nitrogen and sulfur dioxide). With this approach, the Air District selects the most cost-effective strategies to achieve regional standards.
3. As an **air toxic**, which is the approach taken specifically to diesel PM to limit localized exposures. The air toxic approach can be either risk-based (utilizing modeling) or technology-based (limiting emissions from specific sources, such as dry-cleaning facilities or backup generators).

Mr. Douglas mentioned that a fourth potential approach would be to consider climate impacts.

Regulations and Rules

There are 57 Air District rules that directly or indirectly address PM, housed within a range of regulations including those governing permits, open burning, inorganic gaseous pollutants,

hazardous pollutants, and miscellaneous standards of performance. Several PM regulations and rules have been updated since 2012, including a new Regulation 6 on Particulate Matter established in 2018.

Mr. Douglas specifically highlighted **Air District Rule 11-18: Reduction of risk from air toxic emissions at existing facilities**. Recent revisions to this rule reduced the threshold limit on toxic air contaminants by an order of magnitude (from 100 per million to 10 per million), requiring approximately 80 existing permitted facilities to develop plans to reduce their emissions or install best available control technologies. This rule is one example of the Air District's emerging focus on localized, community-specific exposures and health risk. Another example he mentioned is **Rule 6-5: Particulate emissions from refinery fluidized catalytic cracking units**, which was recently revised to further reduce localized PM emissions from refineries.

Forthcoming Air District Work

Localized Sources

As the Air District turns increasing attention to localized health impacts of PM for disproportionately impacted communities, it is exploring further regulation regarding:

- **Restaurants,**
- **Wood smoke,** and
- **Indirect or magnet sources** (e.g. warehouses, which do not directly emit PM, but attract PM-producing traffic such as diesel trucks).

PM as an Air Toxic

The Air District is also engaged in exploring the possibility of approaching undifferentiated PM as an air toxic. The present constraint is that the Air District has relied on the State of California's list of toxic air contaminants, which does not include undifferentiated PM. Air District rulemaking that treats PM as a toxic could potentially be developed, independent of state-level air toxics regulations, if the Air District is able to identify appropriate methodology to perform health risk assessments.

Post-Presentation Discussion

Shifting focus to greenhouse gas emissions and global warming? Council Member Rudolph asked how a hypothetical emphasis on climate impacts would shift the Air District's approach to PM regulation. Mr. Douglas responded that reducing climate impacts is a co-benefit of the other three approaches to PM (as a nuisance, criteria pollutant, and air toxic). Mr. Nudd added that an emphasis on climate impacts could shift the Air District's focus more heavily toward black carbon, but that he was uncertain of the effect such a shift would have on health risks.

Council Member Rudolph commented that climate change presents the greatest health risk to the population.

Toxics framework. Chair Hayes asked for clarification on the process by which undifferentiated PM could be introduced into the regulatory framework as a toxic air contaminant. Mr. Bunger explained that the first option was for OEHHA to add undifferentiated PM to its list of air toxics, which would immediately trigger its inclusion in several existing Air District rules including 11-18 (existing facilities) and 2-5 (new source review). The Air District has requested this action from OEHHA, and analysis is underway at the state level, but the Air District does not have the power to compel such action by the State. However, in theory, the Air District does have the ability to independently classify undifferentiated PM as a toxic air contaminant and treat it accordingly. To do so, the Air District would need to identify appropriate methodology to use for health risk assessment. Chair Hayes noted that the Air District already concerns itself with controlling source-specific PM emissions in its modeling regarding attainment of ambient air quality standards. Mr. Bunger clarified that such analysis does not presently apply to every source of PM emissions, as it would if PM were classified as an air toxic. Board Member Sinks asked whether OEHHA has committed to a schedule for evaluating undifferentiated PM for potential inclusion on its air toxics list. Mr. Nudd responded that he does not observe a willingness on the part of OEHHA to enact statewide recognition of undifferentiated PM as an air toxic in the near term, likely due to present challenges in some parts of the state with meeting existing federal air quality standards. However, he explained that OEHHA is assisting the Air District with its PM analyses, and does appear willing to support the Air District (at least through peer review) if it moves toward independently recognizing undifferentiated PM as a toxic. Mr. Bunger noted that the Air District is also exploring other distinct PM species (besides diesel PM) as air toxics.

Discussion of Draft October PM Symposium Report and Advisory Council Q&A Document

The Advisory Council discussed the draft report on the October PM Symposium prepared by consulting technical writer Elisabeth Andrews on behalf of the Air District, available online at <https://www.baaqmd.gov/news-and-events/conferences/pm-conference>.

The Advisory Council briefly considered potential updates such as revising the “topics for further exploration” identified in the draft report into Advisory Council findings and creating further content for the “Next Steps” section. Chair Hayes also introduced the prospect of incorporating an additional document into the report. That document, which he initiated, provides responses to the questions originally posed by the Advisory Council and the Air District to the October PM Symposium panelists (see Appendix for the list of questions). His aim was to distill the information shared by the panelists into concise answers to each of the questions. Ultimately, the Advisory Council determined that because the purpose of the October PM Symposium report was to serve as a record of the October PM Symposium, it was appropriate to limit that report’s contents to what had been shared during that event.

Edits to Draft October PM Symposium Report. Three clarifying edits were made to the October PM Symposium report draft, all within the section on “Advisory Council Deliberation.” The Advisory Council agreed to release the draft report for public comment following these edits.

Progress of Q&A document. Council Member Solomon volunteered to assist Chair Hayes in further developing the question-and-answer document. Several Advisory Council members made suggestions regarding the draft Q&A:

- Council Members Solomon and Kleinman supported recommending the treatment of PM as a non-threshold toxic. Council Member Kleinman noted that the dose-response relationship appears to be curvilinear rather than linear.
- Council Member Solomon argued for incorporating information from the forthcoming March PM Symposium (focused on community organizations) into the Q&A.
- Council Member Rudolph stated the need to emphasize new evidence for likely causal relationships between PM and specific health effects and the greater sensitivity of vulnerable populations. She also noted the importance of reducing ambient PM levels as much as possible in the presence of events such as wildfires that cannot be placed into a regulatory framework.

Public Comment

Three opportunities were provided for public comment: prior to presentations from Air District staff, following presentations from Air District staff, and toward the close of the meeting following Advisory Council deliberation on the October PM Symposium Summary draft report. A list of the commenters follows; their comments are categorized by topic and summarized below.

List of Commenters

Dr. Ashley McClure, primary care physician, Oakland

Jed Holtzman, 350 Bay Area

Greg Karas, Communities for a Better Environment

Richard Grey, 350 Bay Area

Comments

Structure of public comment. Dr. McClure suggested that comment on agenda items should take place after the agenda items had been discussed by presenters and the Advisory Council. Mr. Holtzman requested that the Advisory Council determine and publicize the timing of public comment periods in advance of Advisory Council meetings. Council Member Borenstein concurred with Mr. Holtzman’s suggestion, and Chair Hayes indicated that the Advisory Council would implement this suggestion by formally determining public comment periods in advance so that people who wish to comment can plan when to be present at Advisory Council meetings.

Urgency. Dr. McClure stated that the October PM Symposium left little ambiguity regarding the health impacts of PM and asked why further symposia were necessary prior to rulemaking. Mr. Holtzman also questioned the pace of progress and the duration of time between meetings. Council Member Borenstein stated that while the Advisory Council was interested in recommending the Air District move toward stricter PM controls, it was not yet clear precisely what the targets should be. He emphasized the importance of measured and deliberative action, as rulemaking is likely to be challenged in court.

Strong statements. Addressing the need to establish a public record to support rulemaking, Mr. Holtzman urged Advisory Council members to “be very fierce in your statements” regarding the implications of the science.

Zero-carbon economy. All four commenters spoke of a need to phase out fossil fuel combustion and transition to a zero-carbon economy. Tying fossil fuel combustion to the climate conditions that have led to increased wildfires, commenters emphasized that reducing

risks from wildfires can only be achieved by reducing the greenhouse gas emissions that ultimately contribute to their frequency.

Air District actions. Commenters recommended specific actions for the Air District:

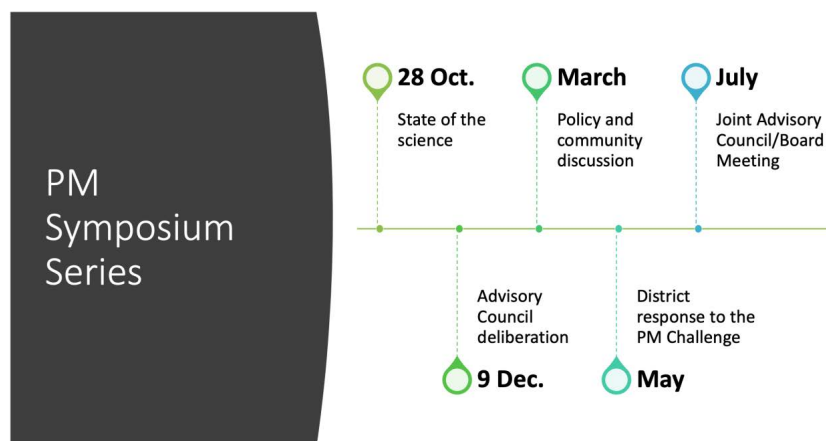
- Set PM threshold levels based on sensitive populations (Holtzman)
- Focus separately on top local and regional sources of PM (Holtzman)
- Update modeling approaches for brake and tire wear and road dust (Holtzman)
- Address agriculture as a source of NH₃ emissions (Holtzman)
- Use fees on PM emitters to support increased instrumentation for speciation (Holtzman)
- Increase attention to black carbon, which has both health and climate impacts (Holtzman)
- Verify low-cost sensors and utilize their data once verified (Holtzman)
- Tighten controls on ultrafine particles, exposure to which is an environmental justice issue as risks are closely associated with proximity to sources (Karas)
- Utilize findings from the California Household Exposure Study, which measured indoor and outdoor PM_{2.5} concentration levels and found both to be higher near refineries (Karas)
- Focus attention on refineries and the oil industry, particularly fluid cracking units (Grey)
- Develop messaging campaigns to help the public recognize the connection between sources of air pollution and health outcomes (McClure)
- Emphasize, possibly at the March PM Symposium, the meaning and values driving the pursuit of tighter air quality controls; “Give us all something to believe in” (McClure)

Partner actions. Commenters also recommended actions that are outside Air District jurisdiction:

- Pursue a tighter state standard for PM (Holtzman)
- Offer free public transit, either on Spare the Air days or at all times (McClure)

Next Steps

The PM Symposium Series continues as depicted in the timeline below. The next symposium will take place on March 24, 2020, in Oakland, focused on presentations from community organizations and leaders. Planning is currently underway.



Following the March symposium, the May event is expected to focus on formulating potential Air District plans to further reduce Bay Area health risks from PM, particularly for disproportionately impacted communities.

The July event brings together the Advisory Council and the Board of Directors to discuss the information and suggestions shared throughout the PM Symposium Series. During this final meeting in the series, the Advisory Council is expected to present its findings to the Board of Directors regarding particulate matter and health in the Bay Area.

Appendix — Questions from the Advisory Council and Air District sent to October PM Symposium Panelists

GENERAL

- What is bullseye in clean air target? How clean is clean enough?
- How will we know when we get to target? What metrics should we use to track progress?
- How do we combine criteria pollutants and toxics? Cancer and non-cancer health endpoints? Short- and long-term effects?
- How can we make sure everyone is treated fairly?
- How can we ensure that everyone breathes clean air?
- What are most important actions that can be taken now? And, in future?

HEALTH EFFECTS PANEL

- Are current PM standards sufficiently health protective?
- Are some species of PM more dangerous than others?
- What is role of ultrafine particles (UFPs)?
- Should form of target expand to account for more than just mass?
- How should we include draft PM ISA's new "likely-causal" health endpoints (nervous system effects, cancer) and new more sensitive populations (children, lower socio-economic status)?
- What are health impacts of high-concentration acute events (e.g., wildfires)? How should we compare them to day-to-day PM impacts?

EXPOSURE AND RISK PANEL

- What are major sources of PM in the Bay Area?
- What PM levels exist in Bay Area? What health risks do they pose?
- How much additional health benefit can be achieved?
- How should we account for spatial scale of effects (i.e., regional versus local-scale impacts, including proximity to major sources)?
- How should we determine which measures would most move public health needle?



BAY AREA
AIR QUALITY
MANAGEMENT
DISTRICT

PM Health Protection Symposium (Advisory Council Meeting of October 28, 2019)

Chair Stan Hayes
Advisory Council
December 9, 2019



PM Focus: Context

- Following three years of **intense wildfire smoke**, focus on **reducing diesel PM** emissions, and conclusion that PM is overwhelming **health risk driver** in Bay Area air
- Air District asked Advisory Council to **focus on PM**
- Provide Advisory Council's take on **latest and best science**, in science-affirming way
- **Assist Air District** to identify those further PM measures that would most move public health needle, especially in most impacted communities



PM Symposia: Overview

- Convened by Advisory Council as **series of meetings**
- Engage **nationally-recognized experts**, including leading experts previously engaged at the Federal level
- **Support Air District** in identifying health-focused “target” guidelines based on latest science, beyond standards already in effect
- Facilitate **Advisory Council feedback** on Air District planning
- Include **local stakeholders**
- Provide **national leadership**

Key Points

- The National Ambient Air Quality Standard (NAAQS) Science Review Process Worked Well Until 2017
- EPA Administrators Pruitt and Wheeler Have **Broken the Process**
- Particulate Matter Science Review By the EPA Clean Air Scientific Advisory Committee (CASAC) is Highly Deficient: **Appropriate to Look Elsewhere**
- Disbanded CASAC PM Review Panel Reconvened Itself
- Key Findings of the Independent Particulate Matter Review Panel



Particulate Matter: Spotlight on Health Protection



BAY AREA AIR QUALITY
MANAGEMENT DISTRICT



Particulate Matter: Spotlight on Health Protection



Date: Oct. 28, 2019 Time: 9:00 am - 4:45pm Advisory Council Chair: Mr. Stan Hayes Facilitator: Jeff McKay

Agenda Items

8:30 AM	Registration/Coffee and light breakfast	Atrium
9:00 AM	Welcome	Board Room
9:25 AM	PM Health Effects Panel	Board Room
11:05 AM	Break	Atrium
11:15 AM	Joint Discussion: Health Effects Panel	Board Room
12:00 PM	Lunch with Keynote Speaker – Former EPA Administrator Gina McCarthy	Yerba Buena
1:15 PM	PM Exposure & Risk Panel	Board Room
2:55 PM	Break	Atrium
3:10 PM	Joint Discussion: Exposure & Risk Panel	Board Room
4:00 PM	Advisory Council Deliberation	Board Room

Additional information

This is a meeting of the BAAQMD Advisory Council.

Public comment will take place during welcome remarks.

For ADA related assistance, please contact Areana Flores at aflores@baaqmd.gov.

375 Beale Street, Suite 600, San Francisco, California 94105 • 415.749.5000 • baaqmd.gov



Particulate Matter: Spotlight on Health Protection

- ~160 registrants
- 2 panels
 - PM Health Effects
 - PM Exposure & Risk
- 9 leading experts

Gina McCarthy

- **Former EPA Administrator**
- Finalized the Clean Power Plan and the Clean Water Rule
- Professor of the Practice of Public Health in the Department of Environmental Health at Harvard T.H. Chan School of Public Health
- Director of the Center for Climate, Health, and the Global Environmental
- Member of the Board of Directors of the Energy Foundation and Ceres
- M.Sc. in Environmental Health Engineering, Planning and Policy from Tuft's University





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 (Draft PM ISA)**
- 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



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
- **CA Scientific Review Panel on Toxic Air Contaminants; CA Air Quality Advisory Committee**



John R. Balmes, M.D.

- Professor of Medicine at UC San Francisco
- Professor of Environmental Health Sciences in the School of Public Health at UC Berkeley
- Director of the Northern California Center for Occupational and Environmental Health
- Authored over 300 papers on occupational and environmental health-related topics
- **Physician Member of the California Air Resources Board**



H. Christopher Frey, Ph.D., F. A&WMA, F. SRA

- Glenn E. Futrell Distinguished University Professor of Environmental Engineering in the Department of Civil, Construction, and Environmental Engineering at North Carolina State University
- Adjunct professor in the Division of the Environment and Sustainability at the Hong Kong University of Science and Technology
- Fellow of the Air & Waste Management Association and of the Society for Risk Analysis
- Ph.D. in Engineering and Public Policy from Carnegie Mellon
- **Former Chair/Member, EPA Clean Air Scientific Advisory Committee (CASAC)**
- **Former Chair/Member, 10 different CASAC NAAQS Review Panels**
- **Chair, Independent PM Review Panel**



Lauren Zeise, Ph.D.

- **Appointed by Gov. Brown as Director of the California Office of Environmental Health Hazard Assessment in December 2016**
- Former Chief of the cancer unit at the California Department of Health Services
- Leading role in OEHHA's development of CalEnviroScreen
- Co-led the team that developed the hazard trait regulation for California's Safer Consumer Products program
- Member, fellow, former editor, and former councilor of the Society for Risk Analysis
- 2008 recipient of the Society's Outstanding Risk Practitioner Award
- Ph.D. from Harvard University



Julian Marshall, Ph.D.

- **Kiely Endowed Professor of Environmental Engineering at University of Washington with a focus on air quality management**
- Founded and runs the Grand Challenges Impact Lab, a UW study abroad program in Bangalore, India
- Associate Editor for Environmental Health Perspectives and Development Engineering
- Published over 100 peer-reviewed journal articles
- Ph.D. in Energy and Resources from UC Berkeley



Scott Jenkins, Ph.D.

- Senior Environmental Health Scientist in EPA's Office of Air Quality Planning and Standards (OAQPS)
- **Currently leading EPA's review of the National Ambient Air Quality Standards (NAAQS) for Particulate Matter (PM)**
- Howard Hughes Postdoctoral Research Fellow in the Department of Cell Biology at Duke University
- Ph.D. in Behavioral Neuroscience from the University of Alabama at Birmingham



Phil Martien, Ph.D.

- **Director of the Assessment, Inventory, & Modeling Division at the Bay Area Air Quality Management District**
- Leading role in the Technical Assessment of AB617's West Oakland Community Action Plan
- Leading role in the Technical Assessment of the Air District's 2017 Clean Air Plan: Spare the Air, Cool the Climate
- Leading role in the Air District's Community Air Risk Evaluation Program
- Ph.D. from UC Berkeley



**PM Health Effects
Panel**



**PM Exposure & Risk
Panel**

Advisory Council Discussion with Experts

BAAQMD's Questions

Example Response

- Are current PM standards sufficiently protective? **Emphatic NO – definitely not for PM_{2.5}.**
- How has the PM health evidence been strengthened? **Better “exposure” models, much larger study populations at much lower levels than before.**
- What new health effects are now recognized? **Strengthening of some causality determinations, but largely the focus is still premature mortality, respiratory morbidity, and cardiovascular morbidity.**
- New endpoints like cancer and central nervous system effects? **Opinions differ.**
- New sensitive groups, like children and lower socioeconomic status, SES, populations? **Growing recognition of “at risk” groups.**
- Are all types of PM equal? **Probably not.** Or, are some more dangerous than others? **Probably. But, more work needed. No components are as yet ‘exonerated.’**
- How severe are PM health risks? **Premature mortality is severe.**
- What additional health benefits can be achieved by further reducing PM to below current standards? **Difficult to quantify with certainty but on the order of tens of thousands of deaths nationally.**

Discussion Questions (EXAMPLE, DO NOT CITE)

Are current PM standards sufficiently health protective?

NOT PROTECTIVE, STANDARDS SHOULD BE LOWERED

Are some species of PM more dangerous than others?

QUITE POSSIBLY BUT NOT ENOUGH INFORMATION, NO PM COMPONENTS “EXONERATED”

What is role of ultrafine particles (UFPs)?

NOT YET CLEAR, TOX STUDIES OF CONCERN, NEED UFP FEDERAL REFERENCE METHOD, MORE MONITORING, EPI STUDIES

Should PM “target” expand to account for more than just mass?

IN RESEARCH ABSOLUTELY, IN REGULATION TOO SOON, UNLESS HIGHLY RISK-AVERSE

How should we include draft PM ISA’s new “likely-causal” health endpoints (nervous system effects, cancer) and new more sensitive populations (children, lower socio-economic status)?

NEW HEALTH EFFECTS AND GROWING RECOGNITION OF “AT RISK” GROUPS IMPORTANT (SUCH AS CHILDREN AND LOW SES), NEED TO CONSIDER

What are health impacts of high-concentration acute events (e.g., wildfires)? How should we compare them to day-to-day PM impacts?

NOT WELL-KNOWN SCIENTIFICALLY BUT OF CONCERN, DATA ON SUB-DAILY EXPOSURES TOO LIMITED AS YET, POTENTIALLY SERIOUS EFFECTS IN EARLY STUDIES, OTHER STUDIES ONGOING, MORE RESEARCH NEEDED



Advisory Council: Initial Deliberation

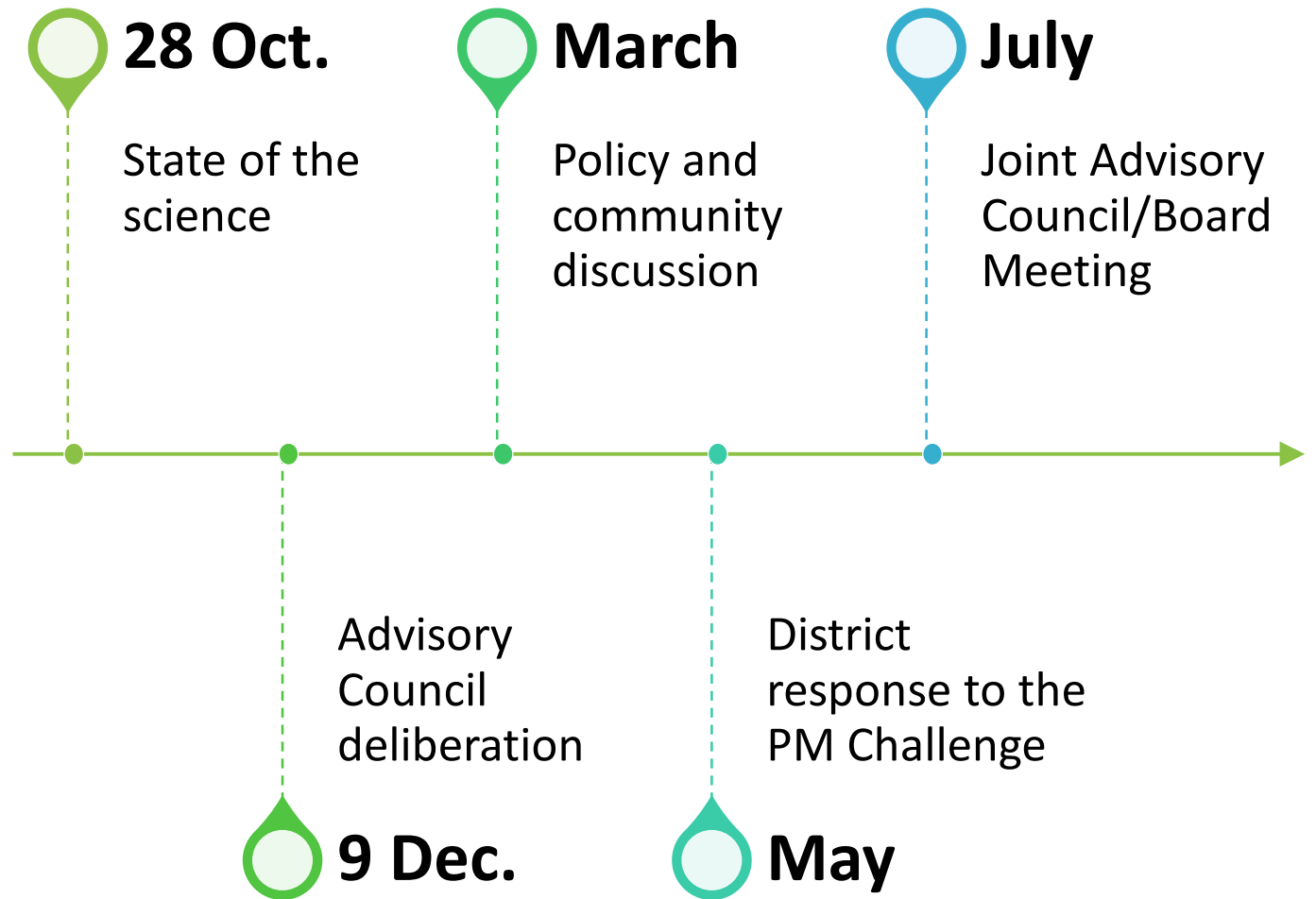
Sense of the Council

- The current standards are **not adequately health protective**.
- Further reductions in PM will realize significant **additional health benefits**.
- We need **more science, and we should act now**.

Further Exploration

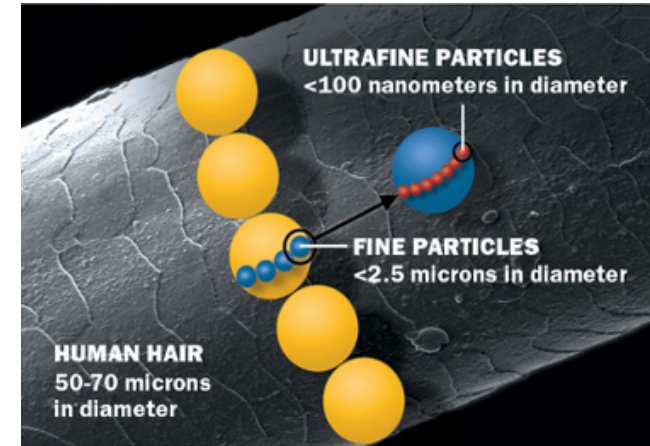
- Treating PM as an **air toxic**
- Expanded monitoring of **UFP**
- Health effects of **acute PM exposures**, e.g., wildfire smoke
- Identifying **PM species** that are particularly dangerous
- Assisting District in identifying strategies having **“highest bang for buck”** for health protection
- Pursuing strategies that have **climate and other co-benefits**

PM Symposium Series



Ambient Particulate Matter (PM)

- PM is a mixture, including particles of differing origin (combustion, crustal, biological) and varying size.
- Multiple sources



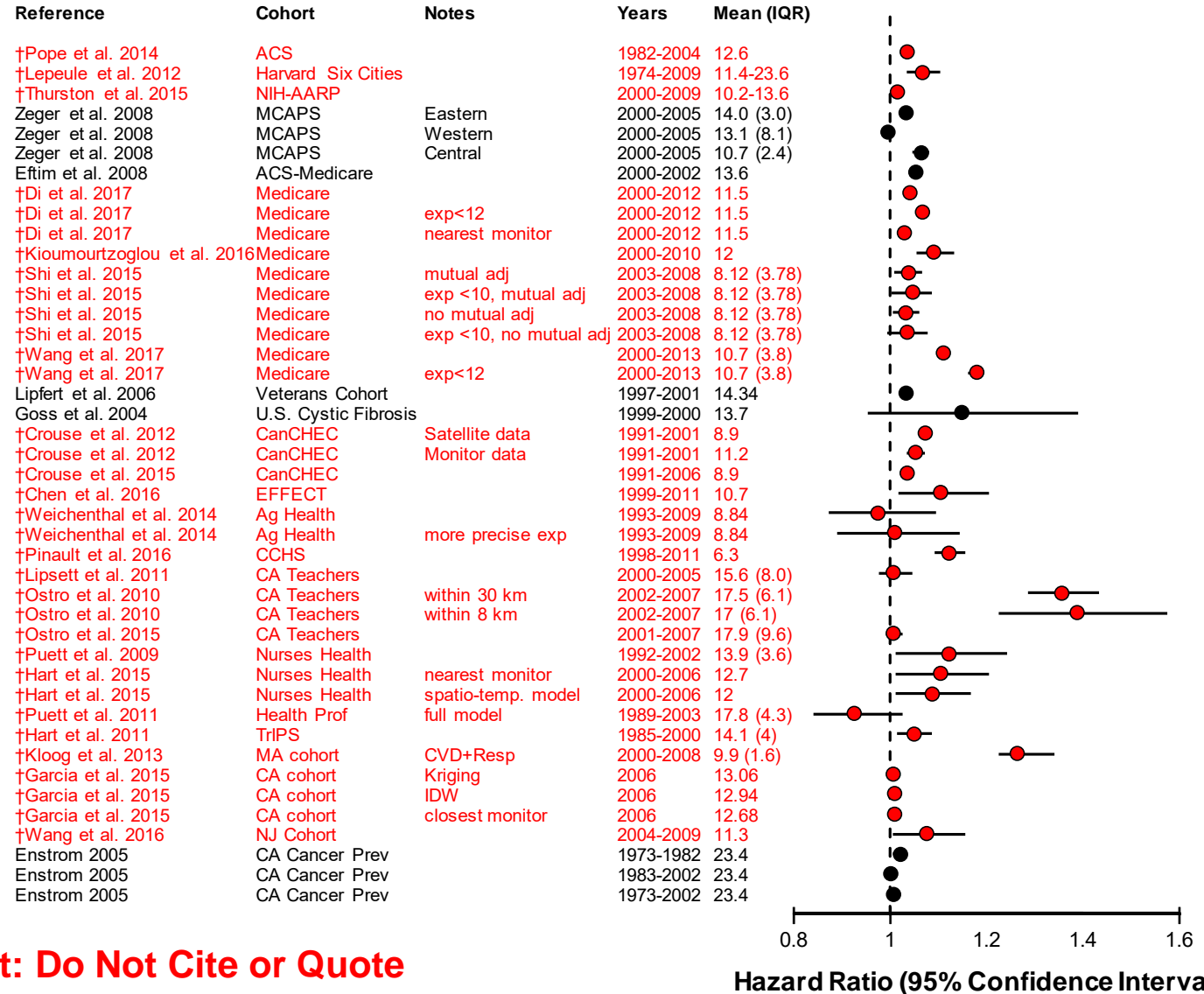
Mortality – Long-term PM_{2.5} Exposure

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/m³ increase in pollutant concentration.

Red = recent studies;
Black = studies evaluated in the 2009 PM ISA



Draft PM ISA Health Effects: Causality Determinations

Table 1-5. Summary of causality determinations for health effect categories for the draft PM ISA.

Draft PM ISA:

- 1,879 pages
- 2,647 references

HUMAN HEALTH EFFECTS						
		ISA	Current PM Draft ISA			
		Indicator	PM _{2.5}	PM _{10-2.5}	UFP	
Health Outcome	Respiratory	Short-term exposure				Respiratory (LIKELY CAUSAL)
		Long-term exposure				
	Cardiovascular	Short-term exposure				Cardiovascular (CAUSAL)
		Long-term exposure	*			
	Metabolic	Short-term exposure	*	*	*	
		Long-term exposure	*	*	*	
	Nervous System	Short-term exposure	*		*	Nervous System (LIKELY CAUSAL)
		Long-term exposure	*	*	*	
	Reproductive	Male/Female Reproduction and Fertility				
		Pregnancy and Birth Outcomes				
	Cancer	Long-term exposure	*	*		Cancer (LIKELY CAUSAL)
	Mortality	Short-term exposure				Mortality (CAUSAL)
Long-term exposure		*	*			

Causal
 Likely causal
 Suggestive
 Inadequate

* = new determination or change in causality determination from 2009 PM ISA

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

Summary of Risk Estimates

Estimates of PM_{2.5}-associated deaths in the full set of 47 study areas

Endpoint	Study	Air quality simulation approach*	Current Standard Absolute Risk (12/35 µg/m ³)	CS (12/35) % of baseline**	Alternative Standard Absolute Risk	
					Alternative Annual (10 µg/m ³)	Alternative 24-hr (30 µg/m ³)
Long-term exposure related mortality						
Ischemic Heart Disease	Jerrett 2016	Pri-PM	16,500 (12,600-20,300)	14.1	14,400 (11,000-17,700)	16,400 (12,500-20,000)
		Sec-PM	16,800 (12,800-20,500)	14.3	14,200 (10,900-17,500)	16,500 (12,600-20,200)
	Pope 2015	Pri-PM	15,600 (11,600-19,400)	13.3	13,600 (10,100-17,000)	15,400 (11,500-19,200)
		Sec-PM	15,800 (11,800-19,600)	13.4	13,400 (9,970-16,700)	15,600 (11,600-19,400)
All-cause	Di 2017	Pri-PM	46,200 (45,000-47,500)	8.4	40,300 (39,200-41,400)	45,700 (44,500-47,000)
		Sec-PM	46,900 (45,600-48,200)	8.5	39,700 (38,600-40,800)	46,200 (44,900-47,500)
	Pope 2015	Pri-PM	51,300 (41,000-61,400)	7.1	44,700 (35,700-53,500)	50,700 (40,500-60,700)
		Sec-PM	52,100 (41,600-62,300)	7.2	44,000 (35,100-52,700)	51,300 (41,000-61,400)
	Thurston 2015	Pri-PM	13,500 (2,360-24,200)	3.2	11,700 (2,050-21,100)	13,300 (2,330-24,000)
		Sec-PM	13,700 (2,400-24,600)	3.2	11,500 (2,010-20,700)	13,500 (2,360-24,200)
Lung cancer	Turner 2016	Pri-PM	3,890 (1,240-6,360)	8.9	3,390 (1,080-5,560)	3,850 (1,230-6,300)
		Sec-PM	3,950 (1,260-6,460)	9.1	3,330 (1,060-5,470)	3,890 (1,240-6,370)
Short-term exposure related mortality						
All cause	Baxter 2017	Pri-PM	2,490 (983-4,000)	0.4	2,160 (850-3,460)	2,460 (970-3,950)
		Sec-PM	2,530 (998-4,060)	0.4	2,120 (837-3,400)	2,490 (982-3,990)
	Ito 2013	Pri-PM	1,180 (-16-2,370)	0.2	1,020 (-14-2,050)	1,160 (-16-2,340)
		Sec-PM	1,200 (-16-2,400)	0.2	1,000 (-14-2,020)	1,180 (-16-2,370)
	Zanobetti 2014	Pri-PM	3,810 (2,530-5,080)	0.7	3,300 (2,190-4,400)	3,760 (2,500-5,020)
		Sec-PM	3,870 (2,570-5,160)	0.7	3,250 (2,160-4,330)	3,810 (2,530-5,070)

Current annual standard of 12 ug/m³ = ~ 47 thousand deaths per year

Lower annual standard from 12 to 10 ug/m³ = ~ 6-7 thousand fewer deaths per year (13-15%)

* Pri-PM (primary PM-based modeling approach), Sec-PM (secondary PM-based modeling approach)

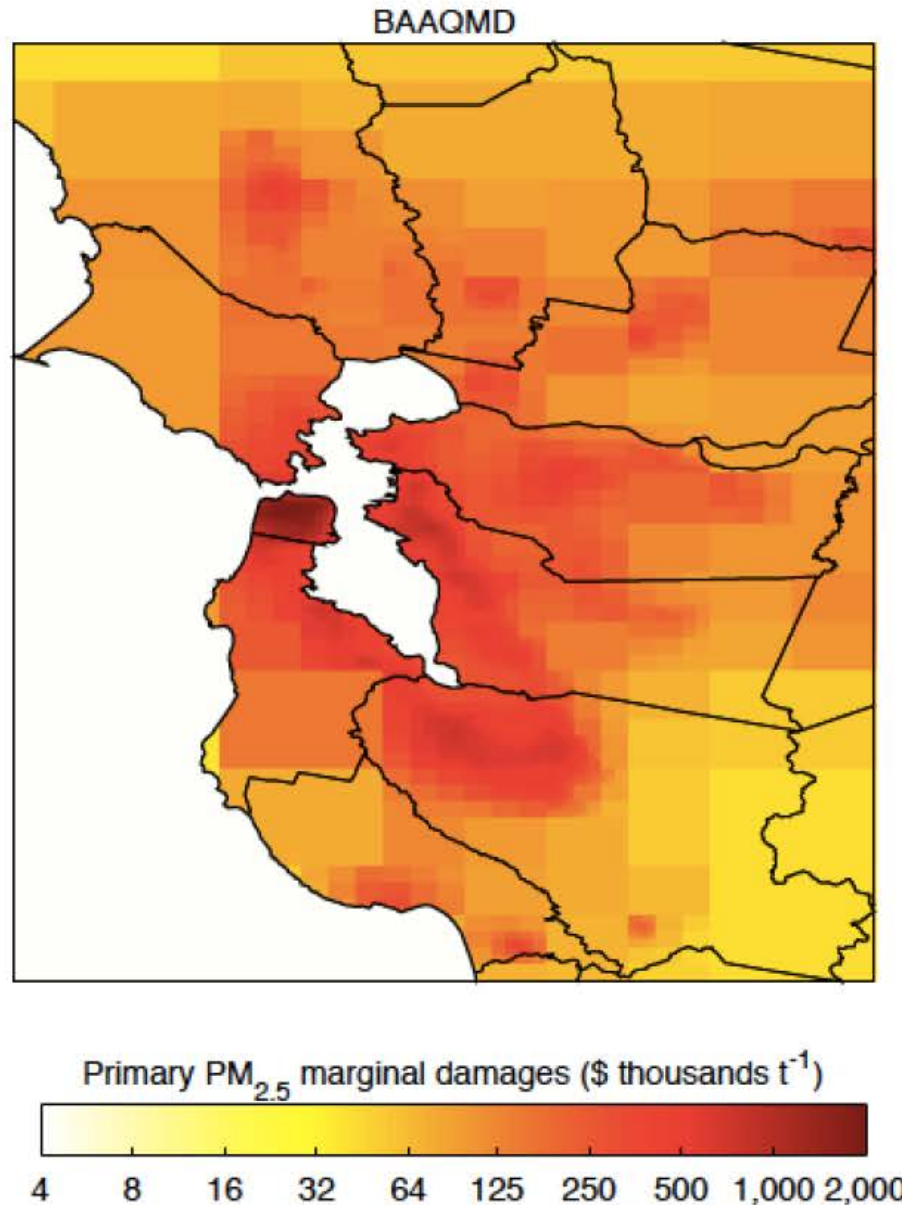
** CS denotes the current standard.

Preliminary Conclusions on the Current Primary PM_{2.5} Standards

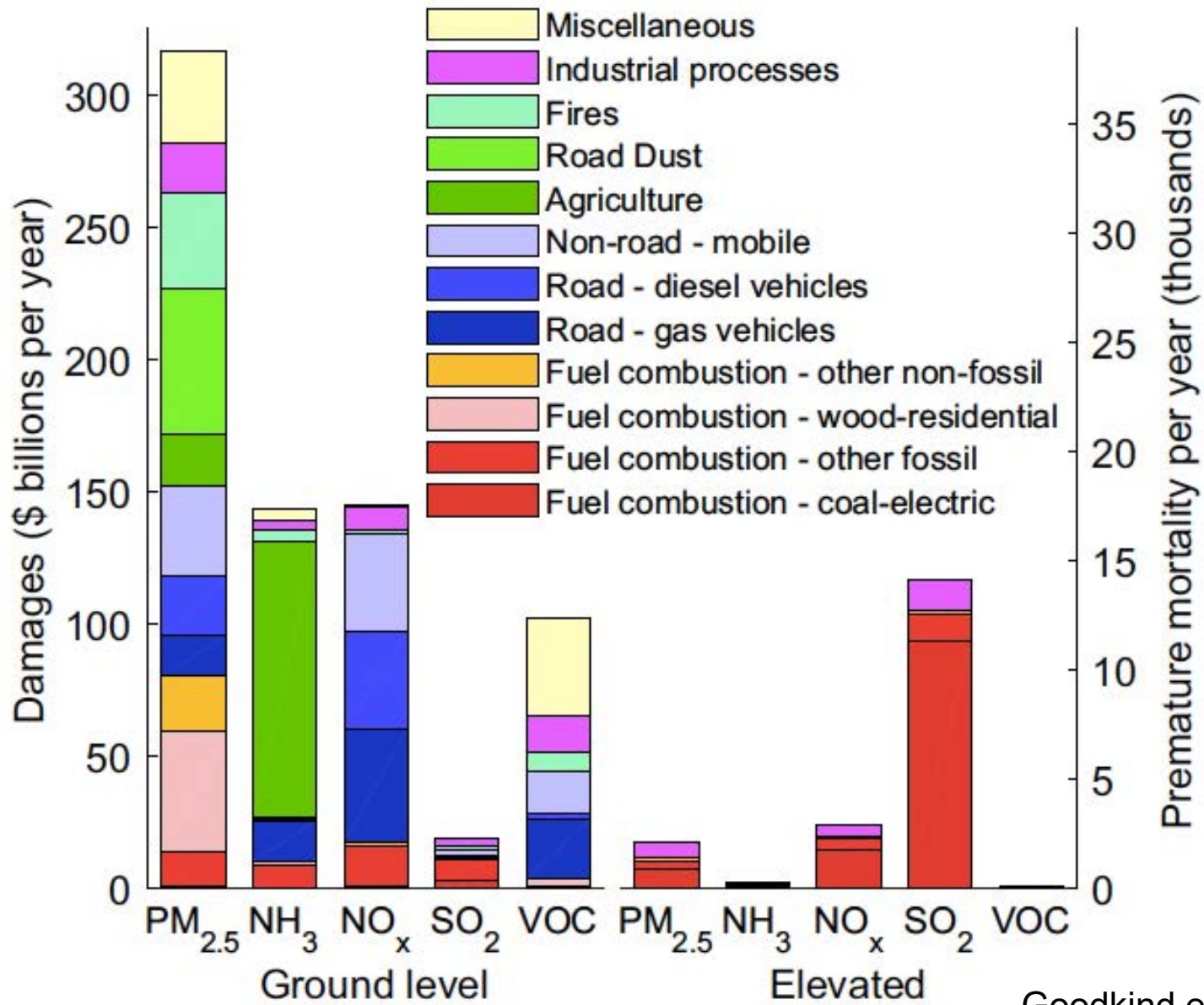
- The available scientific information can reasonably be viewed as calling into question the adequacy of the public health protection afforded by the current annual and 24-hour primary PM_{2.5} standards
- Basis for this preliminary conclusion:
 - Long-standing body of health evidence, strengthened in this review, supporting relationships between PM_{2.5} exposures and various outcomes, including mortality and serious morbidity effects
 - Recent U.S. and Canadian epidemiologic studies reporting positive and statistically significant health effect associations for PM_{2.5} air quality likely to be allowed by the current standards
 - Analyses of pseudo-design values indicating substantial portions of study area health events/populations in locations with air quality likely to have met the current PM_{2.5} standards
 - Risk assessment estimates that the current primary standards could allow thousands of PM_{2.5}-associated deaths per year – most at annual average PM_{2.5} concentrations from 10 to 12 µg/m³ (well within the range of overall mean concentrations in key epidemiologic studies)

**Draft EPA
PM Policy
Assessment
(PA)**

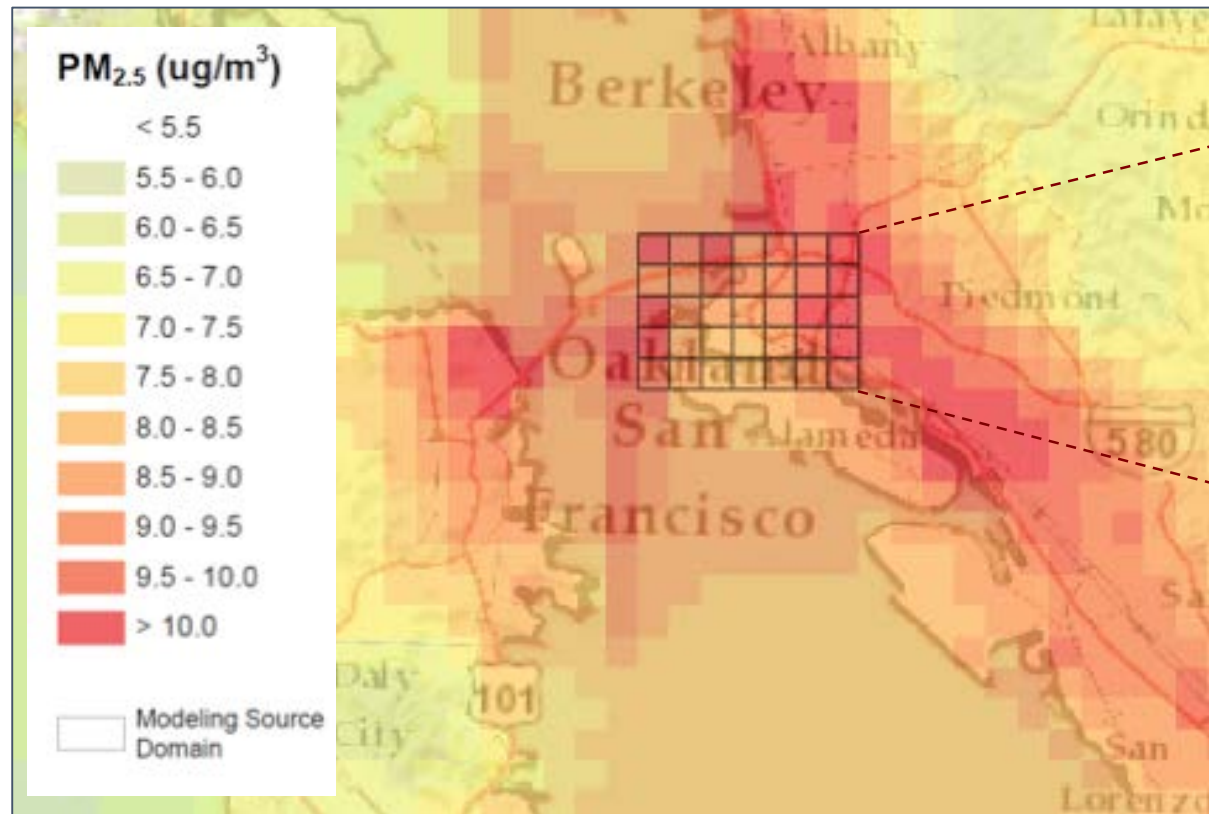
Primary PM_{2.5} Marginal Damages



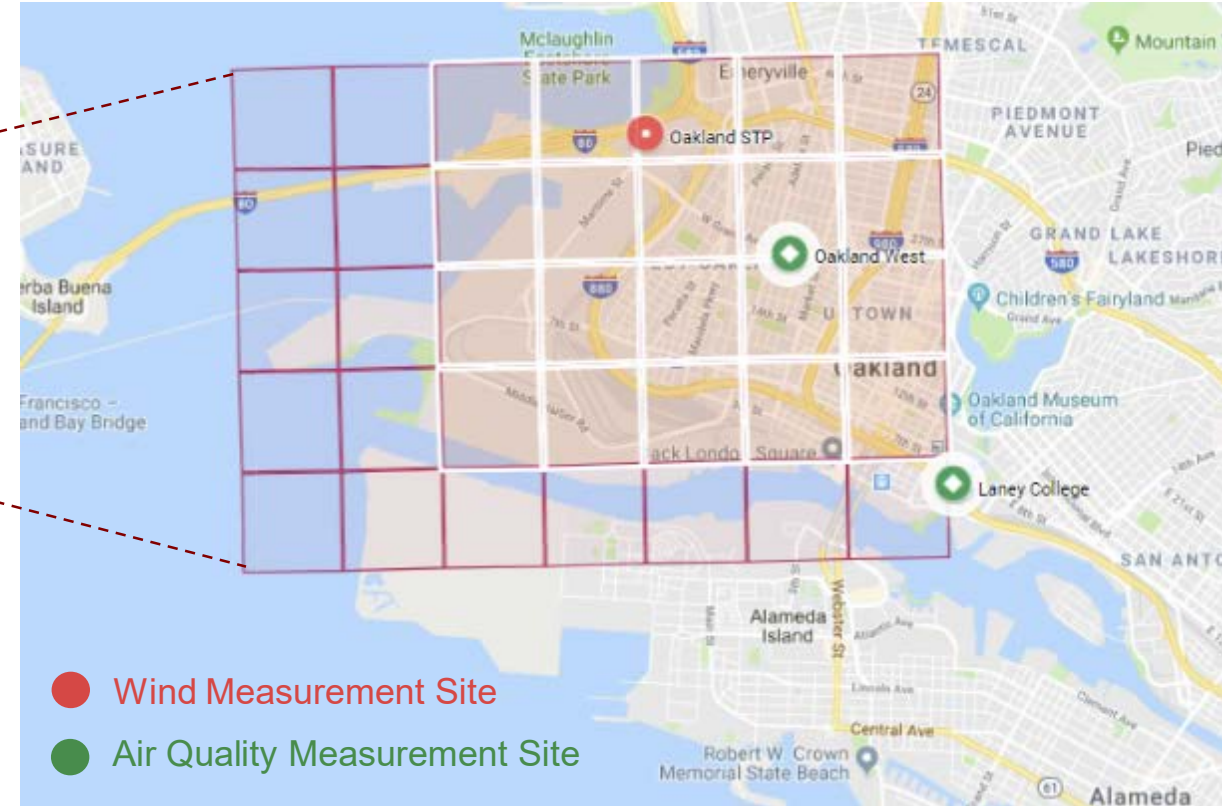
Damages and Premature Mortality



Regional-Scale and Community-Scale Modeling (2017)



Regional-scale modeling: covers the Bay Area



Local-scale modeling: covers West Oakland, including impacts in receptor area (white) from sources in source area (red)

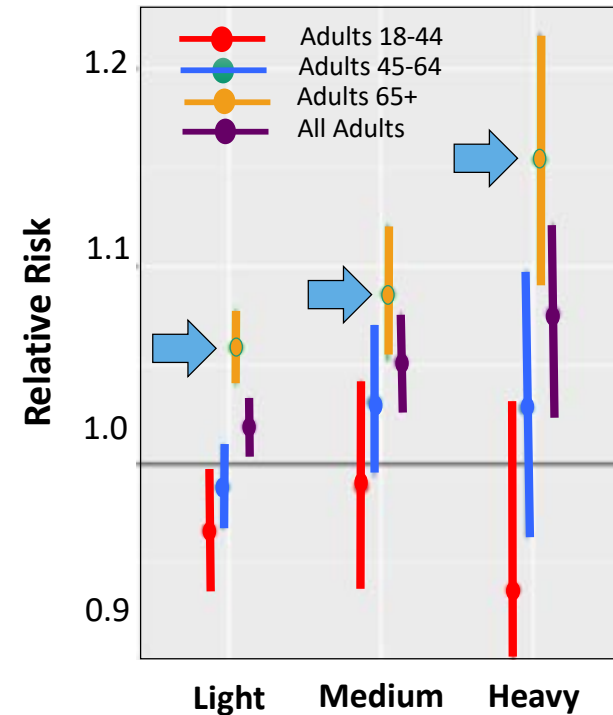
Clear evidence of an association between wildfire smoke and respiratory health

- Asthma exacerbations significantly associated with higher wildfire smoke ***in nearly every study***
- Exacerbations of chronic obstructive pulmonary disease (COPD) significantly associated with higher wildfire smoke in most studies
- Growing evidence of a link between wildfire smoke and respiratory infections (pneumonia, bronchitis)



- **Wildfire-PM_{2.5} associated with heart attacks and strokes for all adults, particularly for those over 65 years old**
- **Increase in risk the day after exposure:**
 - All cardiovascular, 12%
 - Heart attack, 42%
 - Heart failure, 16%
 - Stroke, 22%
 - All respiratory causes, 18%
 - Abnormal heart rhythm, 24%
(on the same day as exposure)

All Cardiovascular Causes



31



BAY AREA
AIR QUALITY
MANAGEMENT
DISTRICT

Update on Particulate Matter (PM)

Air District Work:

Regional-and Local-Scale PM_{2.5} Source Apportionment

Phil Martien, PhD

Director of Assessment, Inventory, and Modeling

Advisory Council Meeting

December 9, 2019

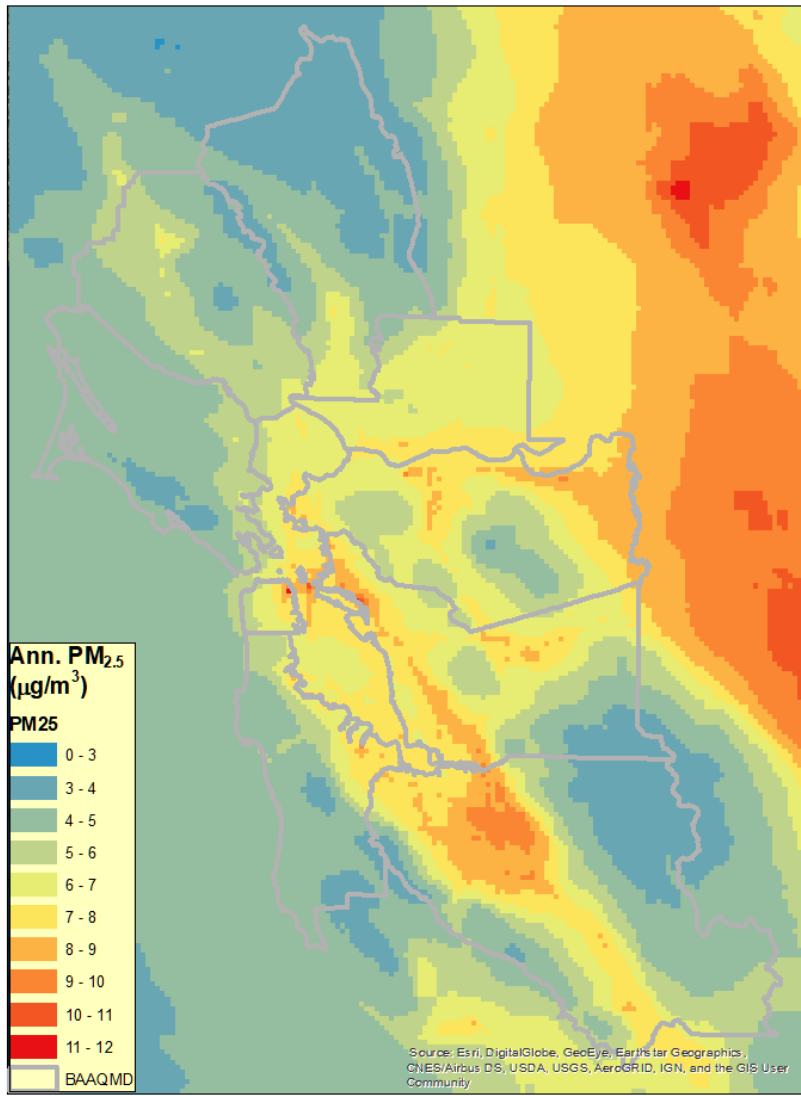


Overview

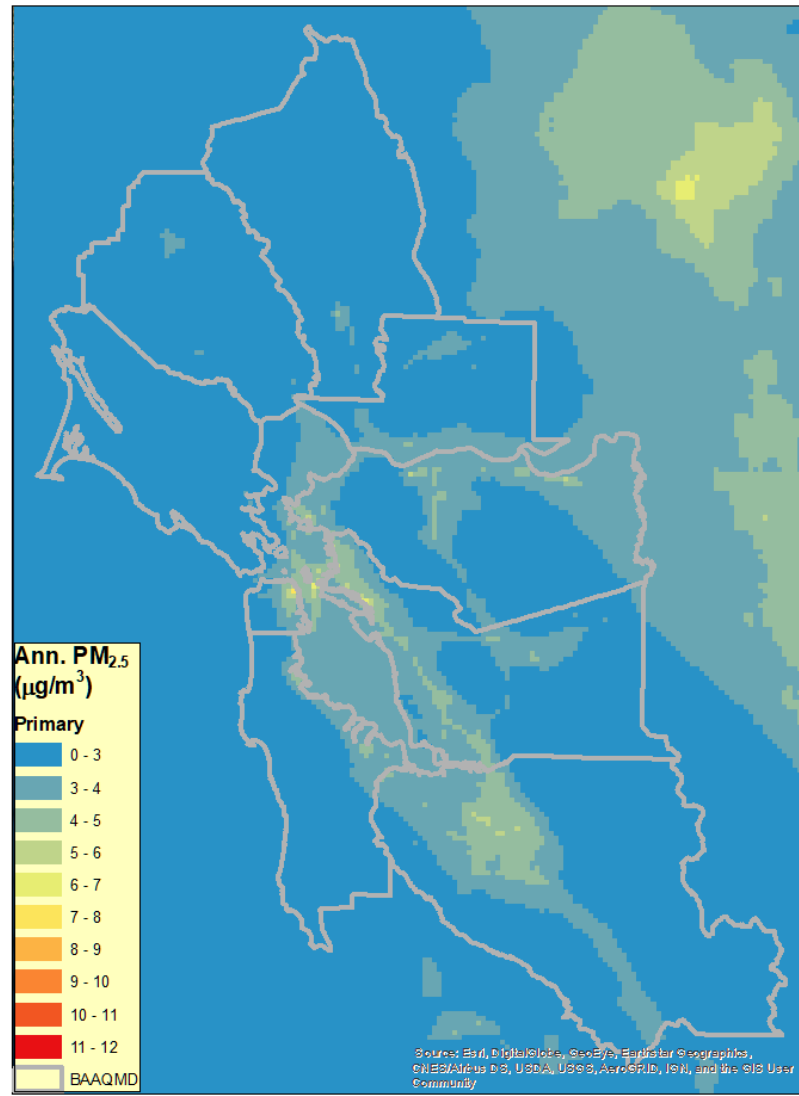
- **Regional-scale PM_{2.5} source apportionment:**
 - Informs actions to maintain attainment of PM standards
 - Reveals information gaps, as top sources are controlled
- **Local-scale PM_{2.5} source apportionment:**
 - Indicates near-source exposures add to total pollution burden
 - Reveals additional information gaps
 - Suggests a regulatory gap: actions to reduce near-source exposures?

Regional Modeling: Primary and Secondary Contributions

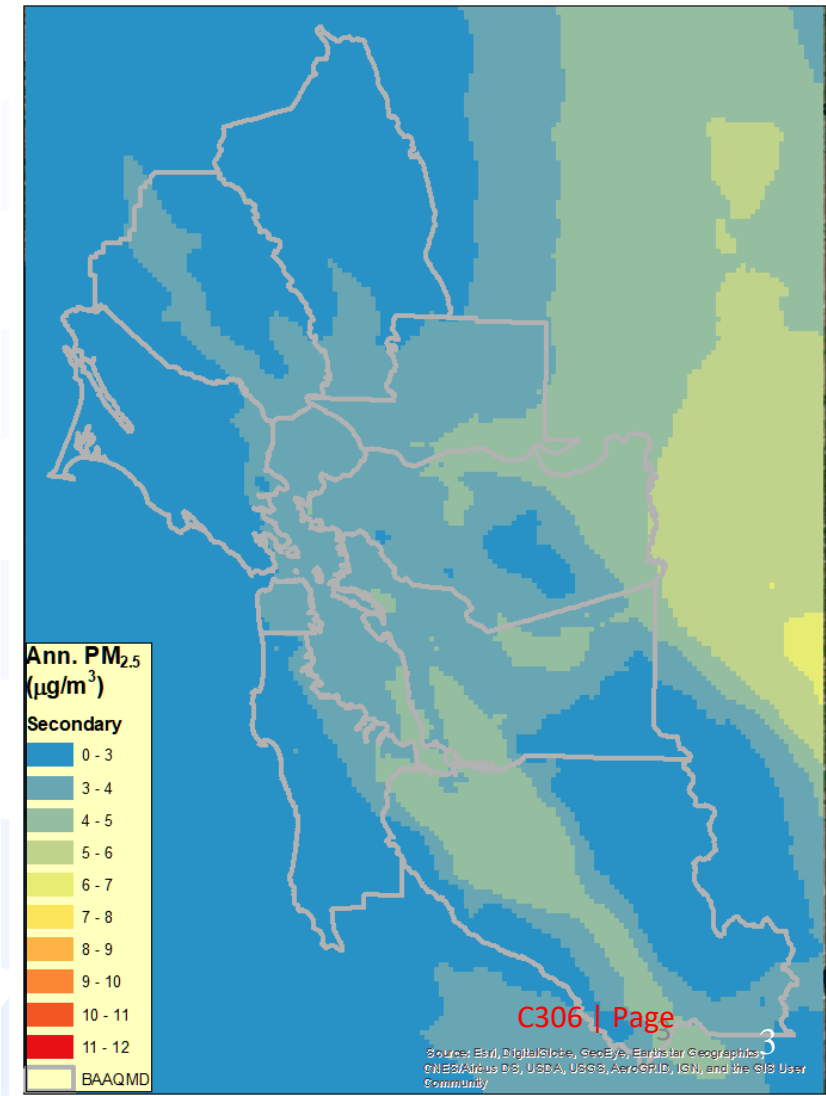
Total PM_{2.5}



Primary PM_{2.5} (about 53%)



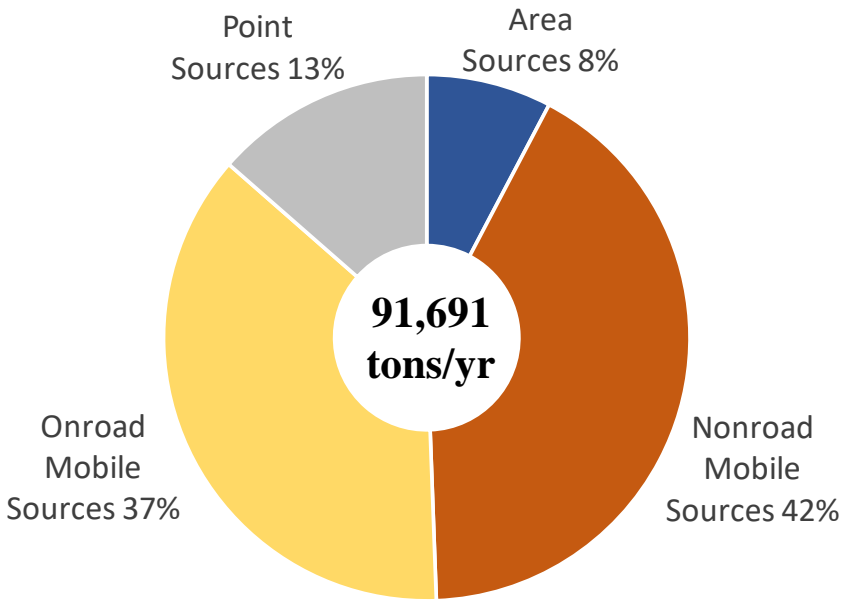
Secondary PM_{2.5} (about 47%)





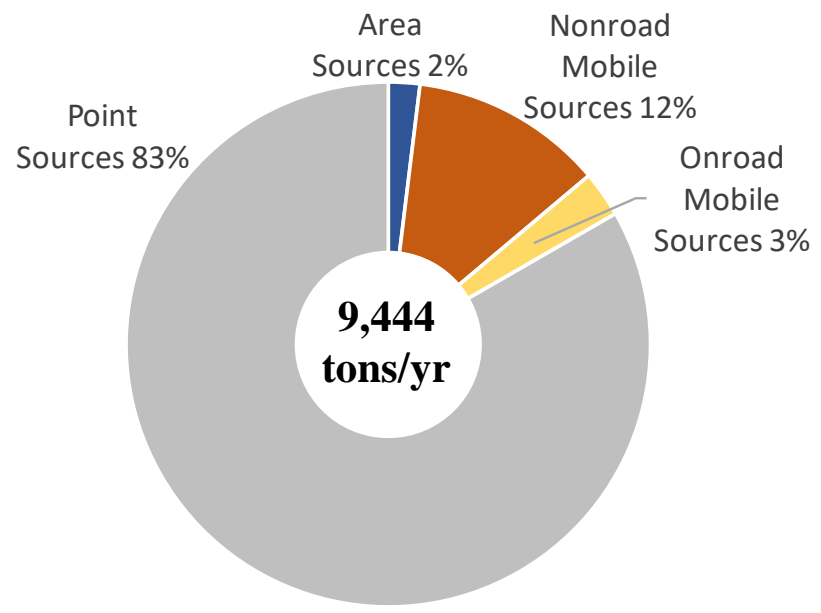
2016 Bay Area Emissions Summary for Key Secondary PM_{2.5} Precursors

NO_x



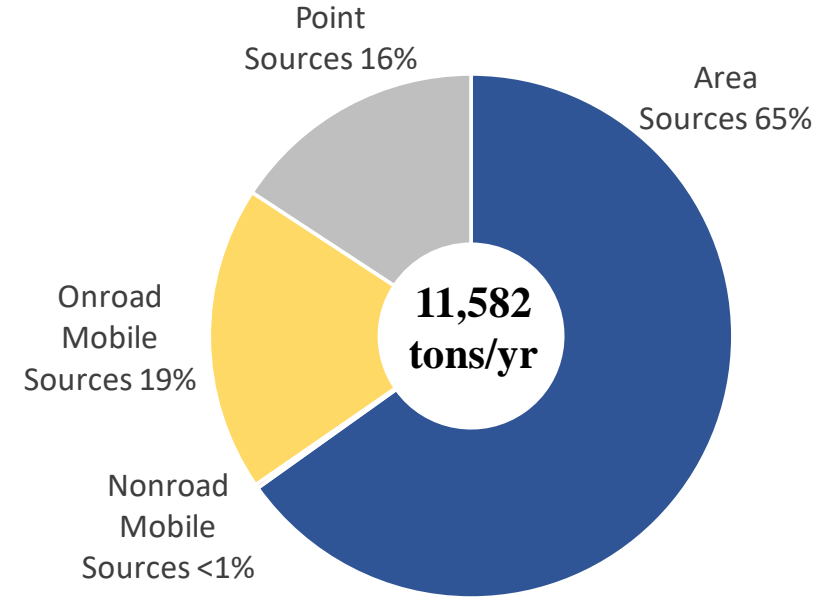
Key NO_x Sources: Diesel trucks and diesel-powered off-road equipment

SO₂



Key SO₂ Sources: Petroleum refineries, manufacturing plants (cement, chemicals)

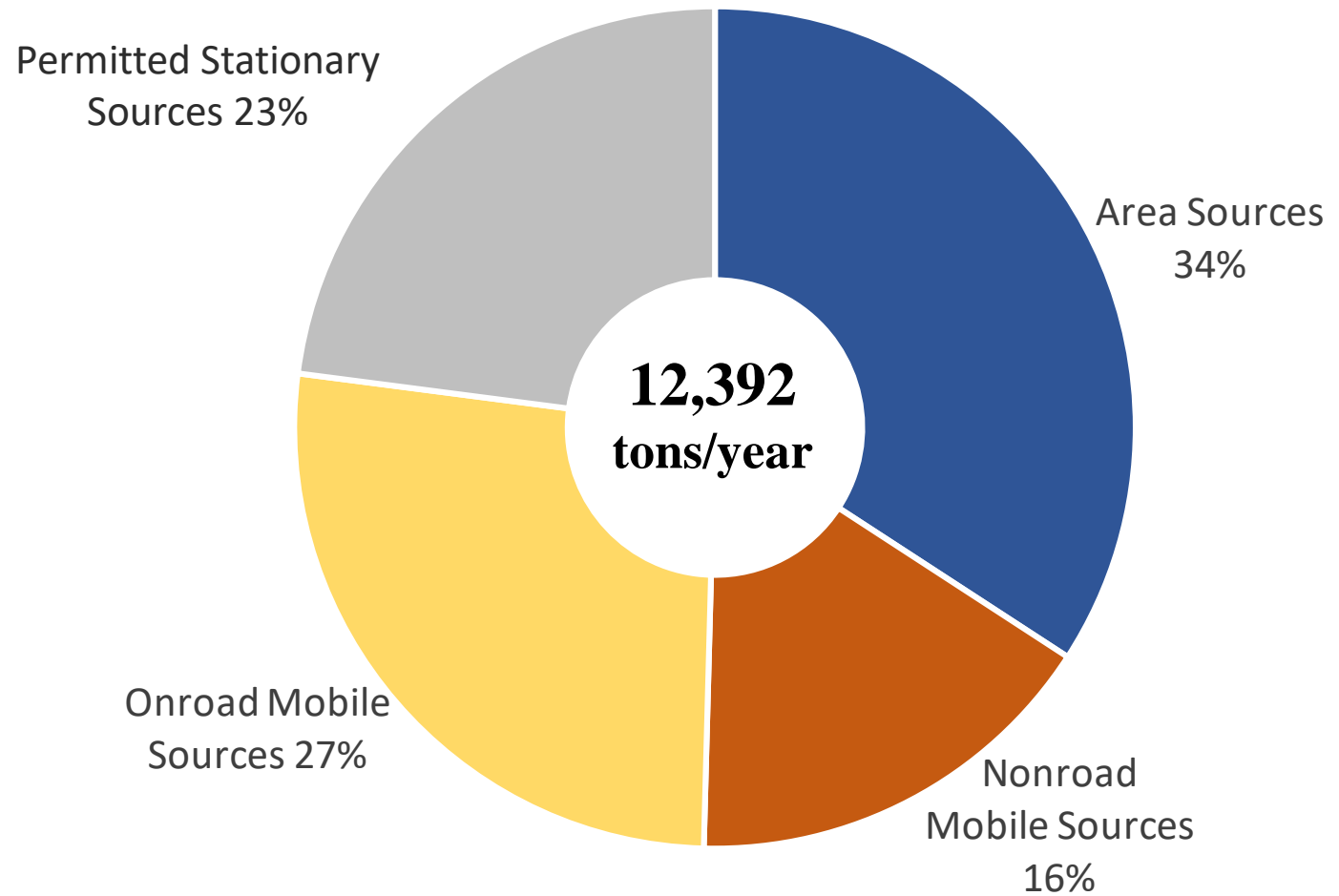
NH₃



Key NH₃ Sources: Agricultural activity (livestock husbandry, fertilizer application)

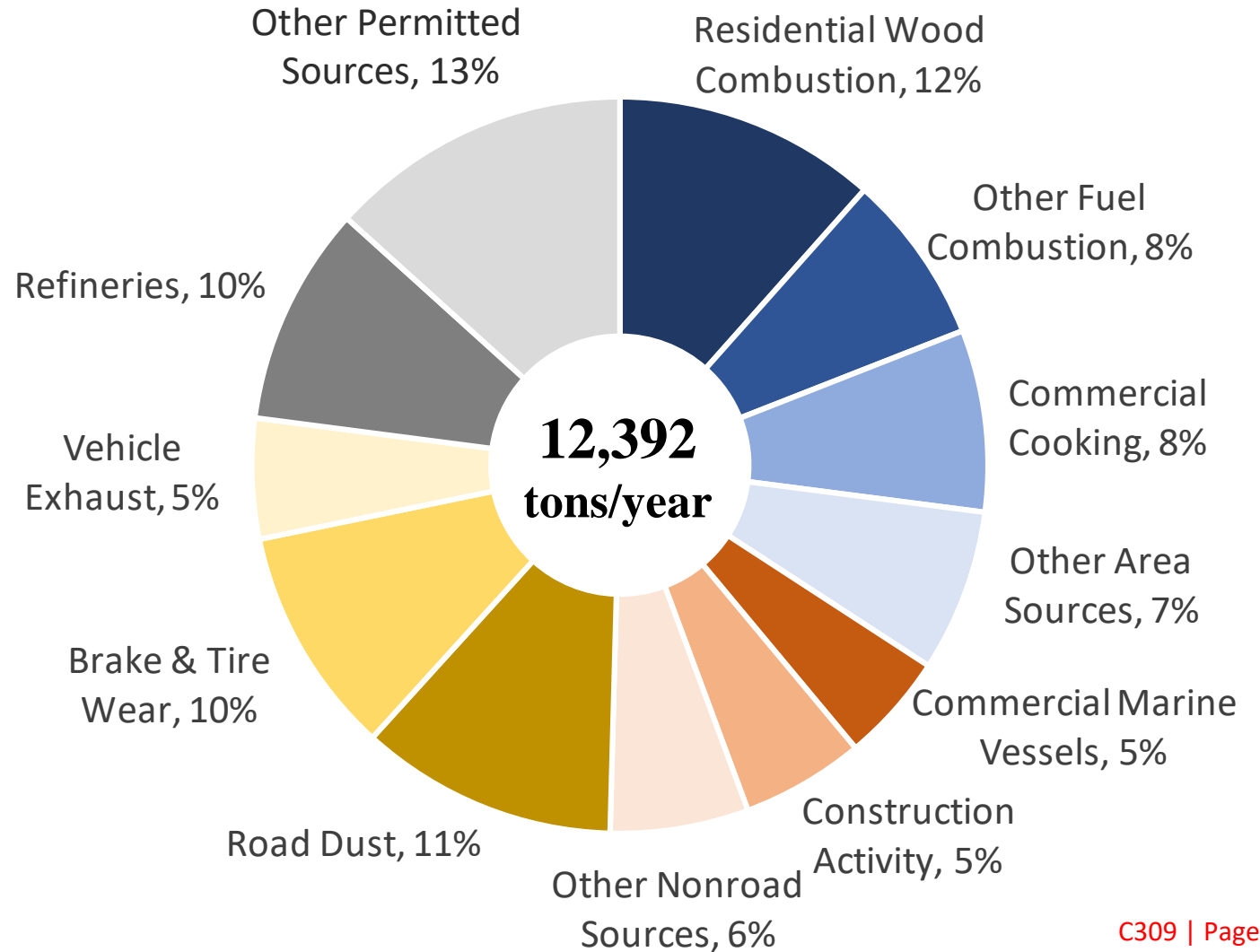
PM_{2.5} Bay Area Emissions Summary for Primary PM_{2.5}

2016 annual
average PM_{2.5}
emissions



PM_{2.5} Bay Area Emissions Summary for Primary PM_{2.5}

2016 annual
average PM_{2.5}
emissions





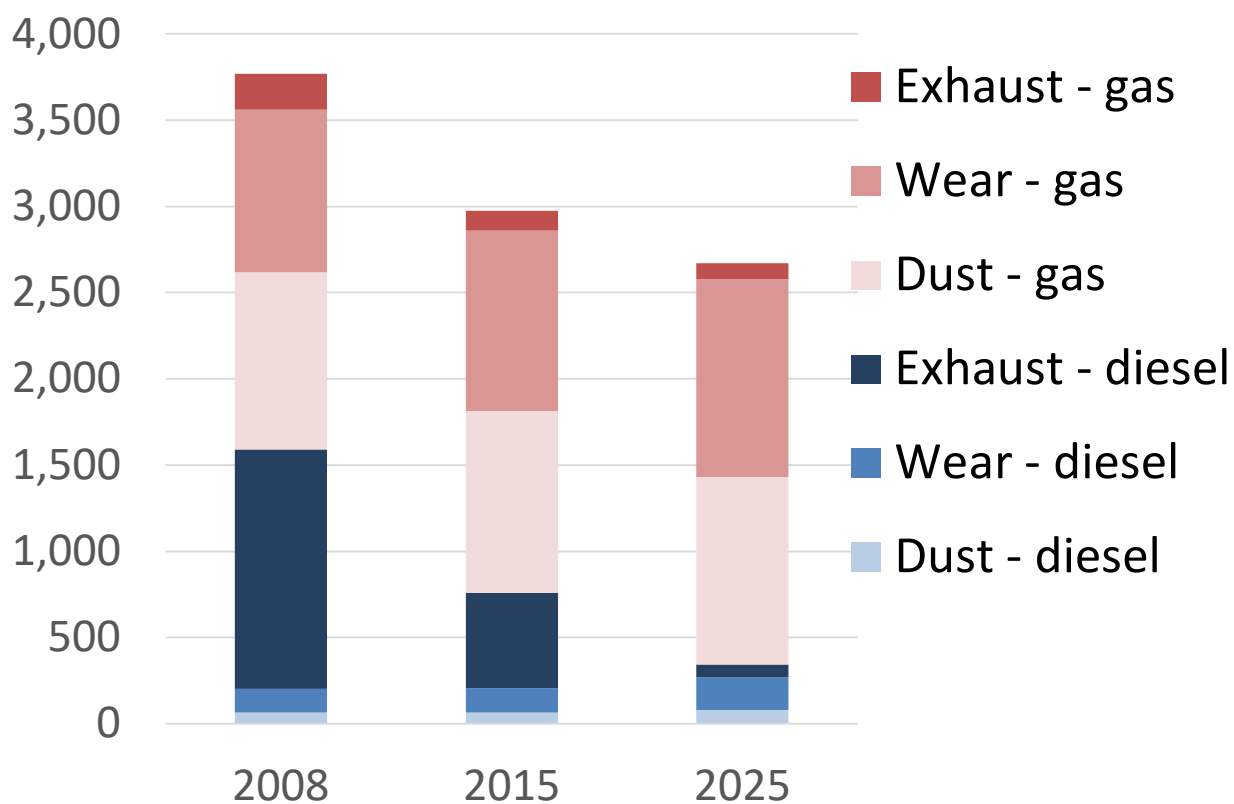
Emissions Inventory Information Gaps

- **On-road wear emissions and road dust**
- **Some area source categories**
 - Residential wood combustion
 - Commercial cooking

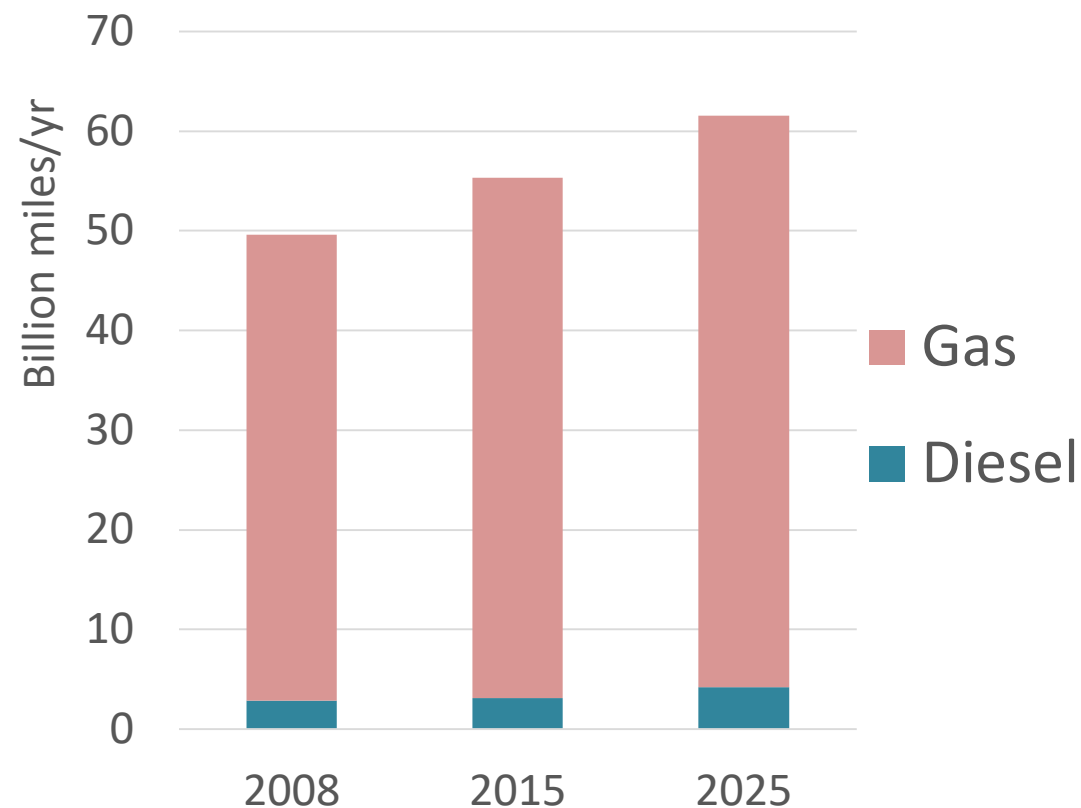


PM_{2.5} Bay Area Emissions Apportionment: On-road Vehicles

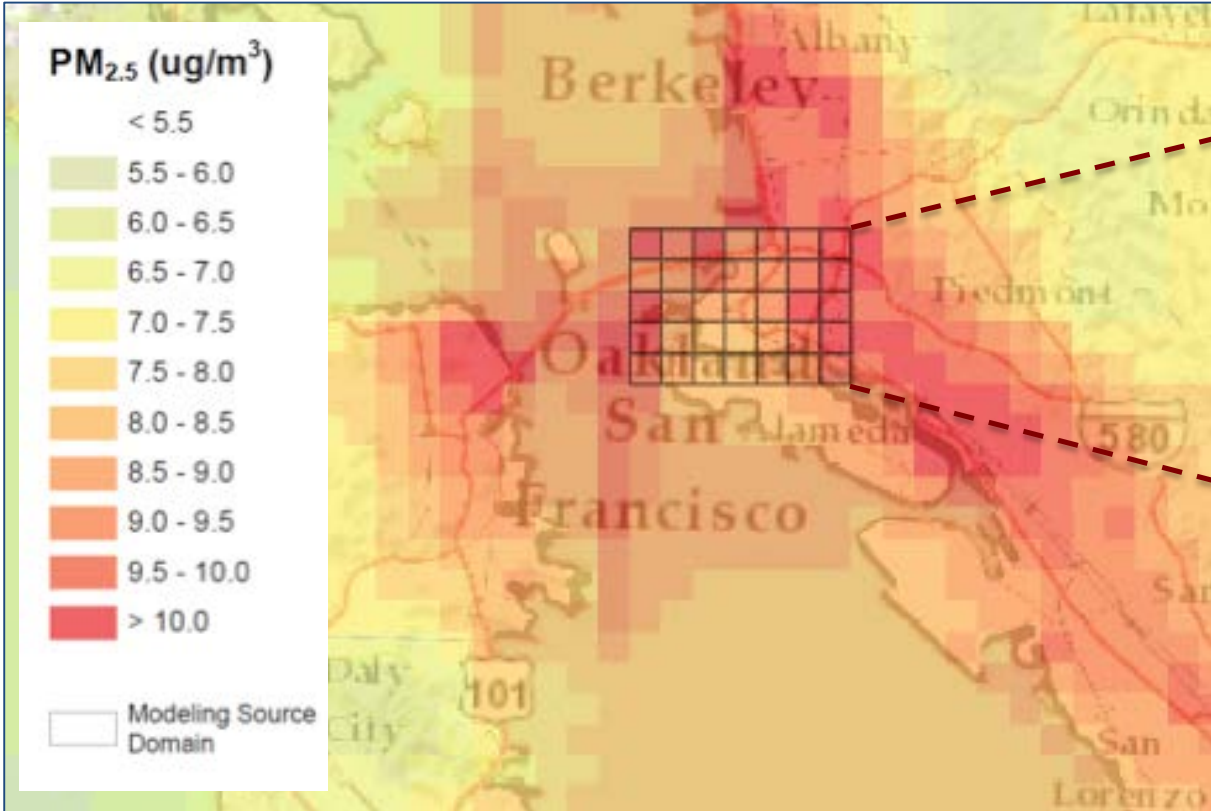
PM_{2.5} (tons/yr)



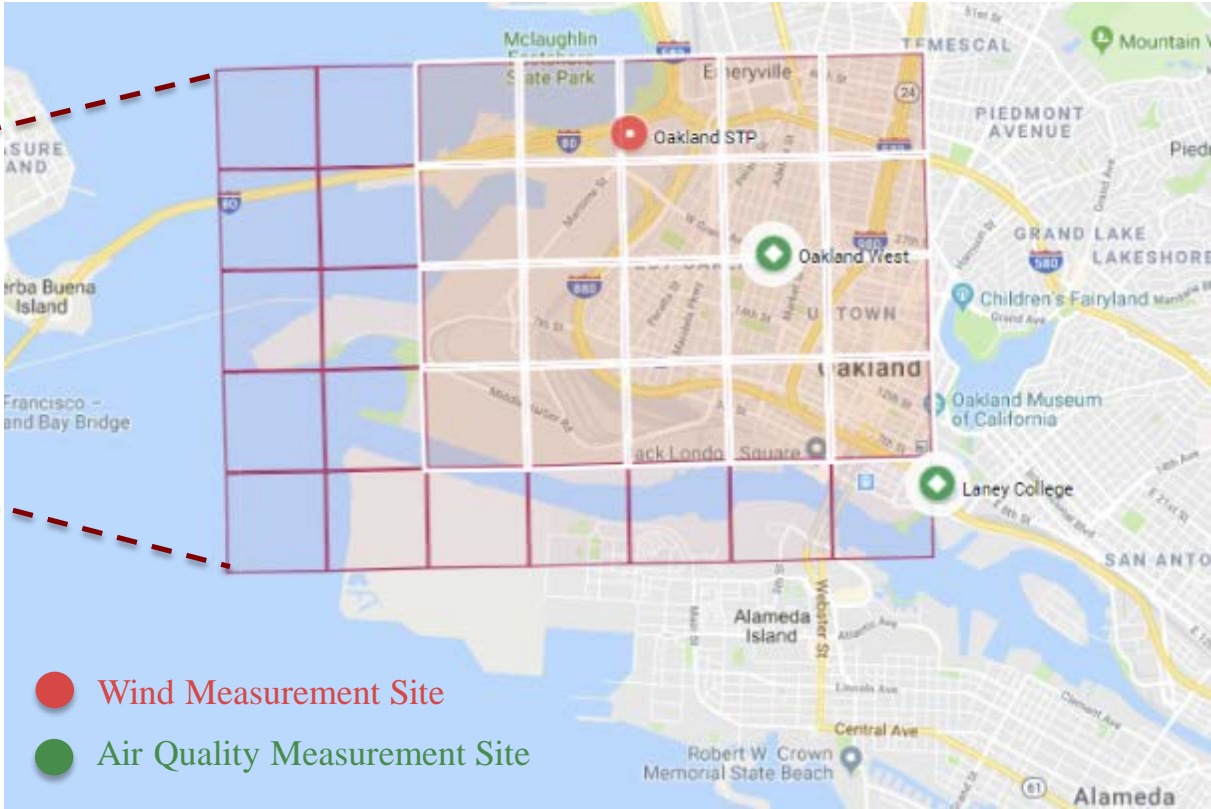
Vehicle Miles Travelled (VMT)



Regional-Scale and Community-Scale Modeling (2017)



Regional-scale modeling: covers the Bay Area



Local-scale modeling: covers West Oakland, including impacts in receptor area (white) from sources in source area (red)

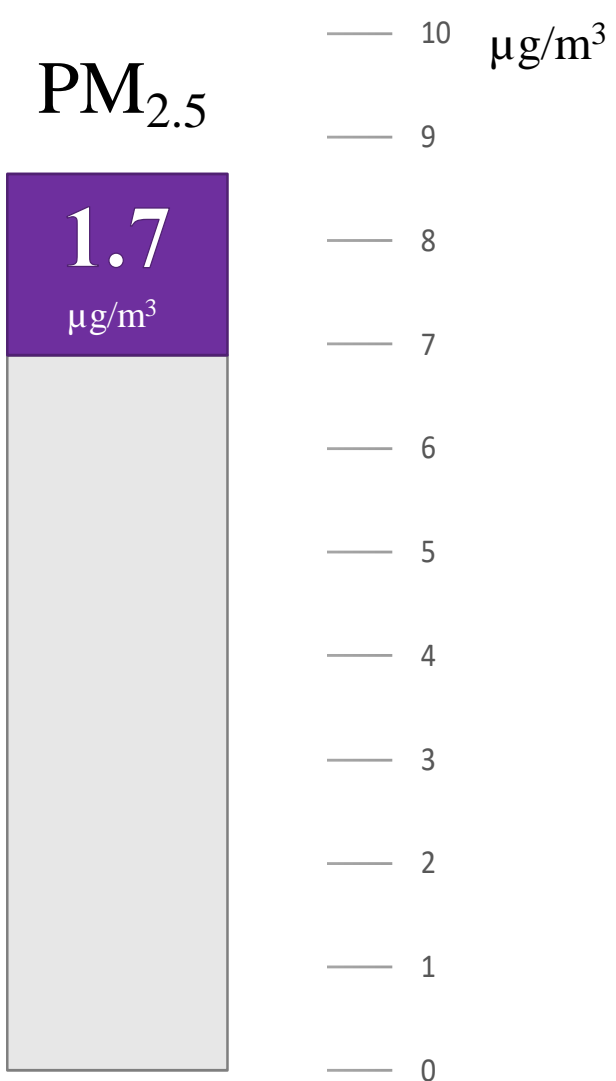
Modeled Primary PM_{2.5} (from Local Sources)*

* 30% of PM_{2.5} sources, including construction, residential woodburning, and restaurants not modeled





Local vs. Regional: West Oakland Example



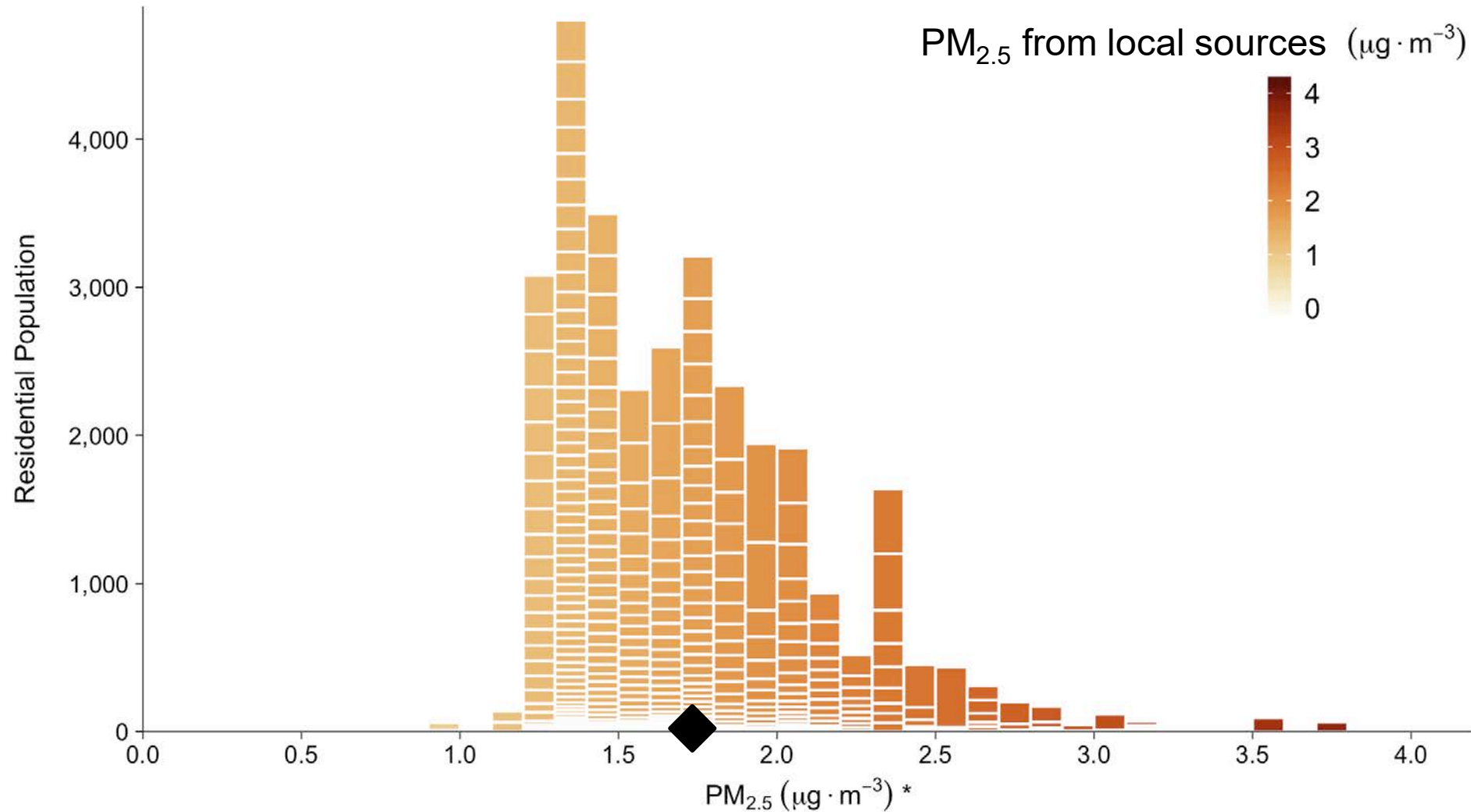
Community-scale model – mapped impacts*



Regional-scale model (minus West Oakland)

*30% of PM_{2.5} sources, including construction, residential woodburning, and restaurants not modeled

Unequal Impacts: PM_{2.5} in West Oakland



* Contributed by modeled "present-day" emissions from existing local sources. Impacts from sources outside West Oakland not included.

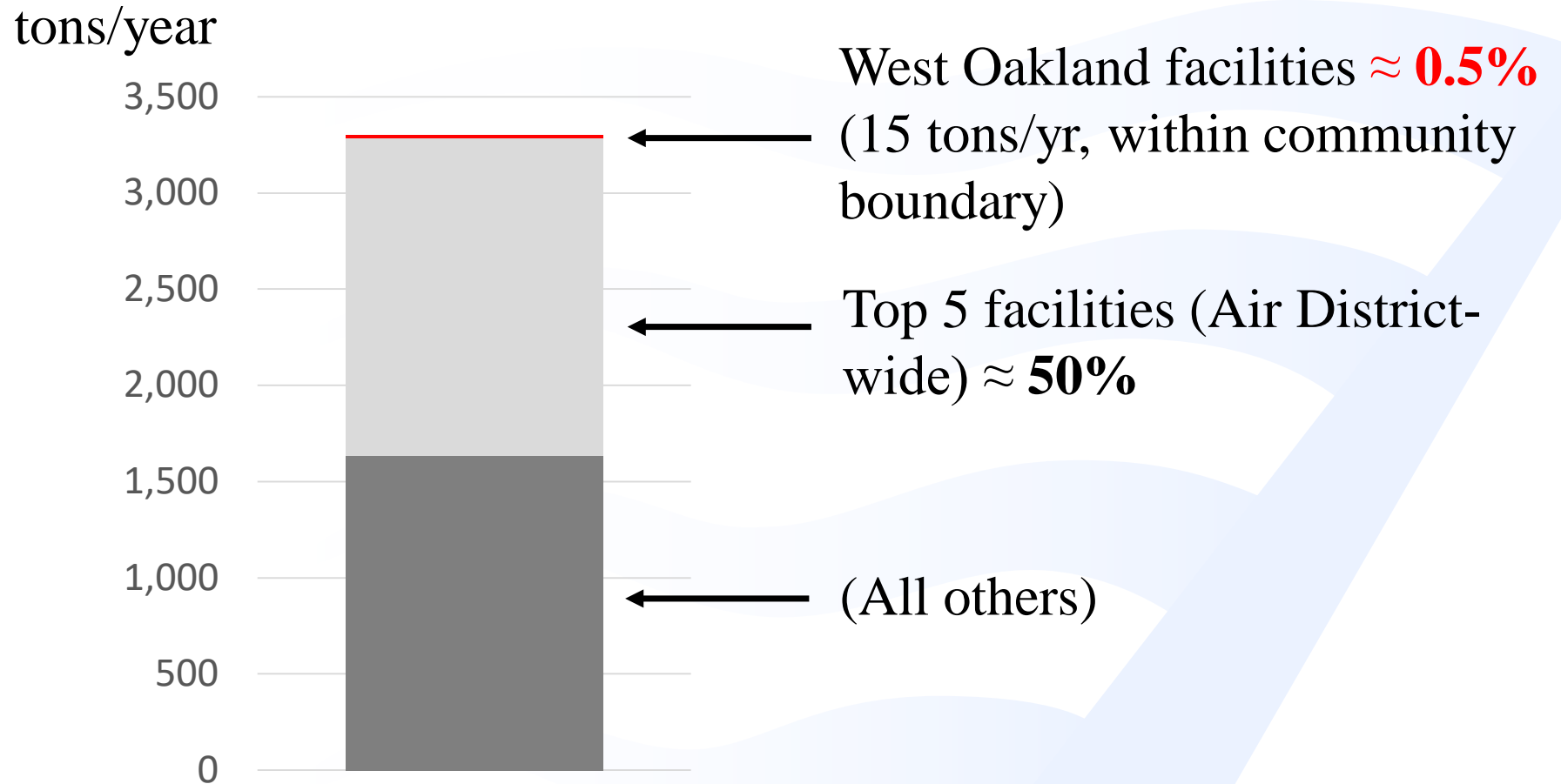


Additional Emissions Inventory Information Gaps Identified

- Local-scale exposures: a different lens for evaluating priorities
- Same concerns about on-road wear and road dust emissions estimates
- We require more information about permitted sources that are not top priorities from a regional perspective



PM_{2.5} Emissions (tons/yr) from Permitted Facilities





Summary

- Continuing regulatory programs to reduce PM_{2.5} with the current regional focus will improve health throughout the Bay Area
- As top sources are controlled, new sources become priorities and we identify new information gaps
- Local-scale assessments bring to focus the importance of some permitted sources that are a low priority from a regional perspective
- A regulatory gap: a framework that promotes PM_{2.5} reductions from near-source exposures will improve health in Assembly Bill 617 communities



BAY AREA
AIR QUALITY
MANAGEMENT
DISTRICT

Update on Particulate Matter (PM) Air District Work:

Monitoring

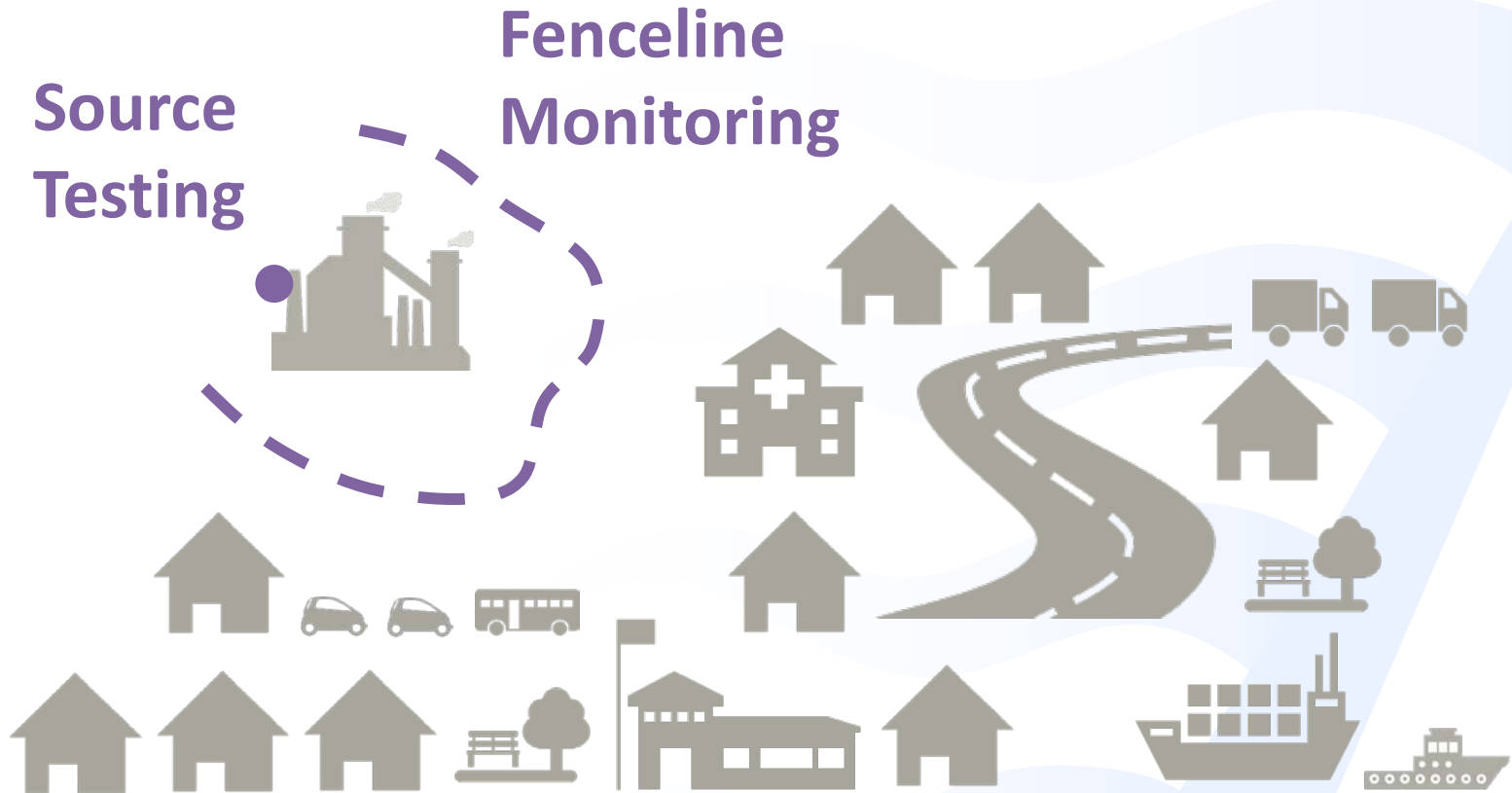
Ranyee Chiang
Director of Meteorology & Measurements

Advisory Council Meeting
December 9, 2019

Measurements in the Bay Area



Measurements in the Bay Area (cont.)



Measurements in the Bay Area (cont.)



Measurements in the Bay Area (cont.)



Sensor Networks

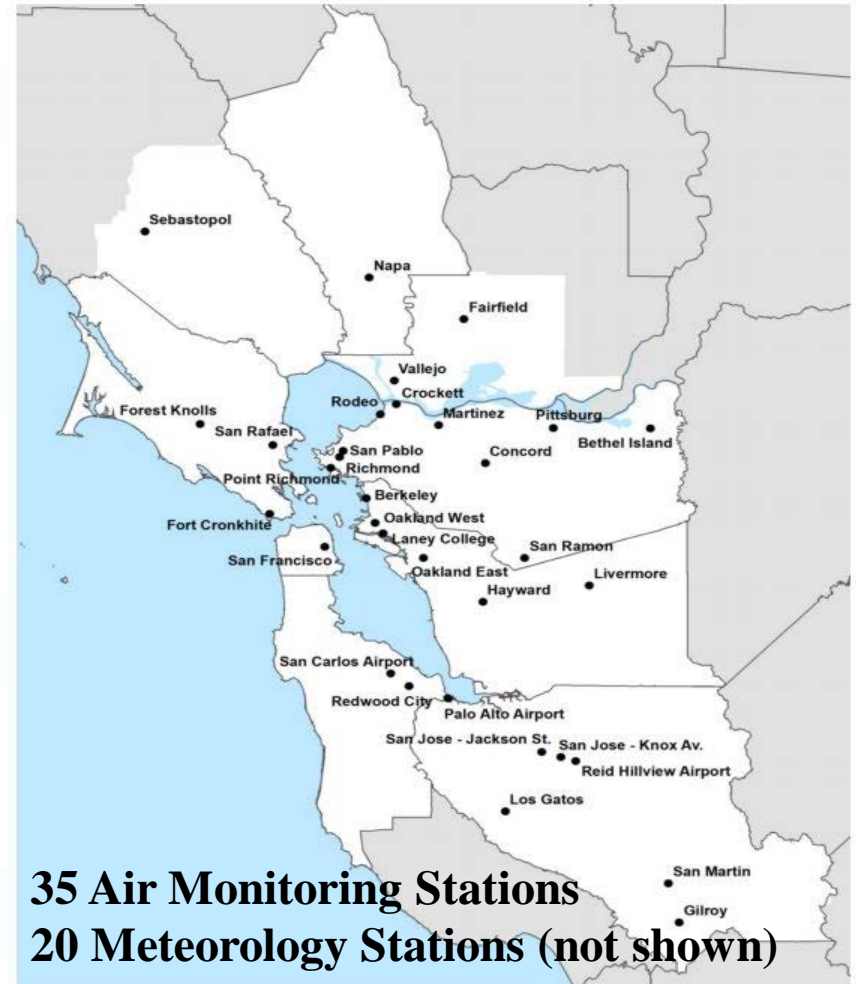


Outline: PM Monitoring

- Regional Network and Community Monitoring
 - Current capabilities
 - New developments
- What does the data show?
 - Ultrafine particles
 - Wildfire incidents
- Looking ahead
 - How could data be used
 - Options to strengthen air quality monitoring

Regional/Regulatory Network: Objectives

- Provide timely ambient air quality data to the general public
- Air quality forecasting for Spare the Air Program
- Support compliance with California and national ambient air quality standards
- Support air pollution research studies



Monitoring Network Design Criteria

- Site Types
 - Population-oriented
 - Highest concentration of pollutants
 - Source-oriented (downwind of major pollution sources)
 - General background sites
 - Regional transport (near borders of the Air District)
- Based on population (2010 Census or estimates)
 - Number of monitoring sites in the Bay Area exceeds the required number

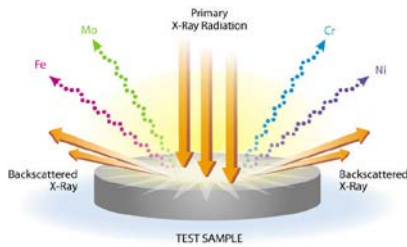


40 Code of Federal Regulations 58 Appendix D

Particulate Matter (PM) Measurements

Mass Measurements

- Compliance with California and National PM_{10} and $PM_{2.5}$ standards
- Designate areas as attainment or nonattainment

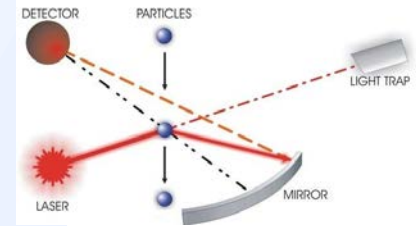


Chemically Resolved or Speciated Data

- Support emission reduction strategies






Particle Counts

- Explore science on emissions, air quality impacts, and health effects associated with exposures





Air District PM Instrumentation

	PM ₁₀ Mass	PM _{2.5} Mass	PM _{2.5} Speciation	Ultrafine Particles (PM _{0.1})	Black Carbon Mass
Analytical methods	Gravimetric	Gravimetric or Filter-based beta attenuation	Chemical extraction	Laser-based particle counter	Filter-based light attenuation
Active monitors	7	20	4	6	7
Example photo					

Ultrafine PM Monitoring

Strengths:

- 7+ years of experience with deployment in diverse siting applications
- Current data can be used to understand diurnal and seasonal patterns, trends, or differences between background, near-road, and typical urban settings



Limitations:

- Cost (\$60k - \$100K / unit)
- Instruments in PM-burdened areas require frequent maintenance
- Difficult to assess sources and sinks
- Data may not be robust enough to link to specific health impacts

New Developments: Hyperlocal, Street-by-Street Monitoring

- Partnership with Aclima to determine differences in air quality on a highly localized scale
- Sensor-based instrumentation (NO_x, CO, O₃, BC, PM_{2.5})
- Data reported through a public portal
- Began in Richmond-San Pablo in summer 2019; entire Bay Area within two years

Use cases:

- Empower communities with information about air quality typical of where they live and work
- Identify areas having elevated background concentrations for further investigation



New Developments: Mobile Laboratory



- High accuracy, real-time instrumentation to screen for PM and air toxics at a local scale
 - PM concentration
 - Inferred particle age
 - Size-binned measurements (ultrafine through PM₁₀)
 - Black carbon
 - Potential to test for chemical components of PM in the future

Use cases:

- Identify and prioritize local sources of air toxics or PM
- Air quality between fixed-site monitors
- Identify locations for portable or fixed-site monitoring stations

New Developments: Portable Platforms

- High quality, battery powered, filter-based PM samplers that are relocatable
- Self-contained “suitcase” for continuous, real-time measurements using high quality, low power instruments

Use cases:

- Concentration variations throughout the day or week near an identified PM hotspot
- Measure air quality when the power is out due to high winds and fire hazard
- Verify low-cost sensor nodes





Outline: PM Monitoring

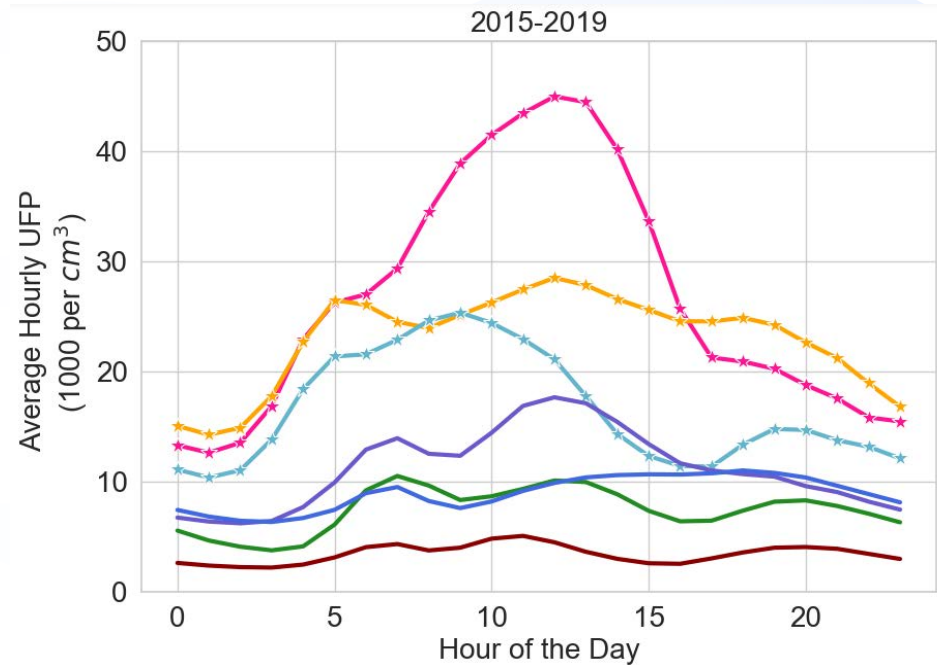
- Regional Network and Community Monitoring
 - Current capabilities
 - New developments
- What does the data show?
 - Ultrafine particles
 - Wildfire incidents
- Looking ahead
 - How could data be used
 - Options to strengthen air quality monitoring

What Do the Ultrafine Particulate (UFP) Data Show?

Levels influenced by traffic and/or photochemical reactions

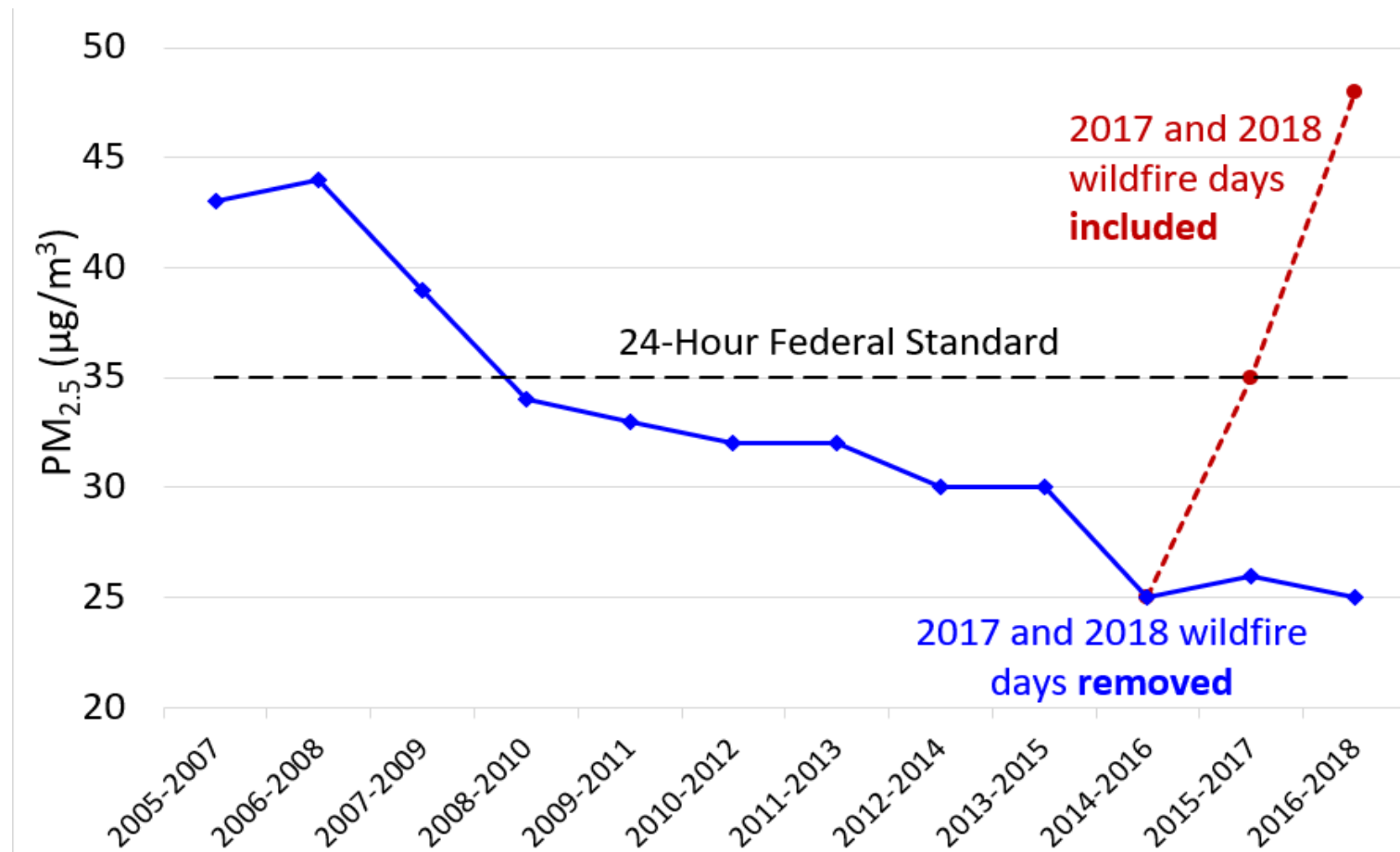
- UFP highest at near-road sites
- Some sites consistently low, while others vary

Patterns of UFP throughout region differ from $PM_{2.5}$



- Laney College (near road)
- San Jose - Knox Ave (near road)
- Berkeley Aquatic Park (near road)
- San Pablo - Rumrill
- Redwood City
- Livermore - Rincon Ave
- Sebastopol

Wildfire Smoke Dramatically Affects Bay Area PM_{2.5} Levels



Air District's Strategy to Reduce Impacts from Wildfire Smoke



Communication with the public

- Issue smoke advisories and Spare the Air alerts based on air quality forecasts
- Understanding air quality measurements and data
- How to reduce exposure during smoke impacts



Grants and incentives for recovery assistance



Work with other Air Districts and Public Health Officers

- Consistent wildfire health information
- Provide guidance for schools



Outline: PM Monitoring

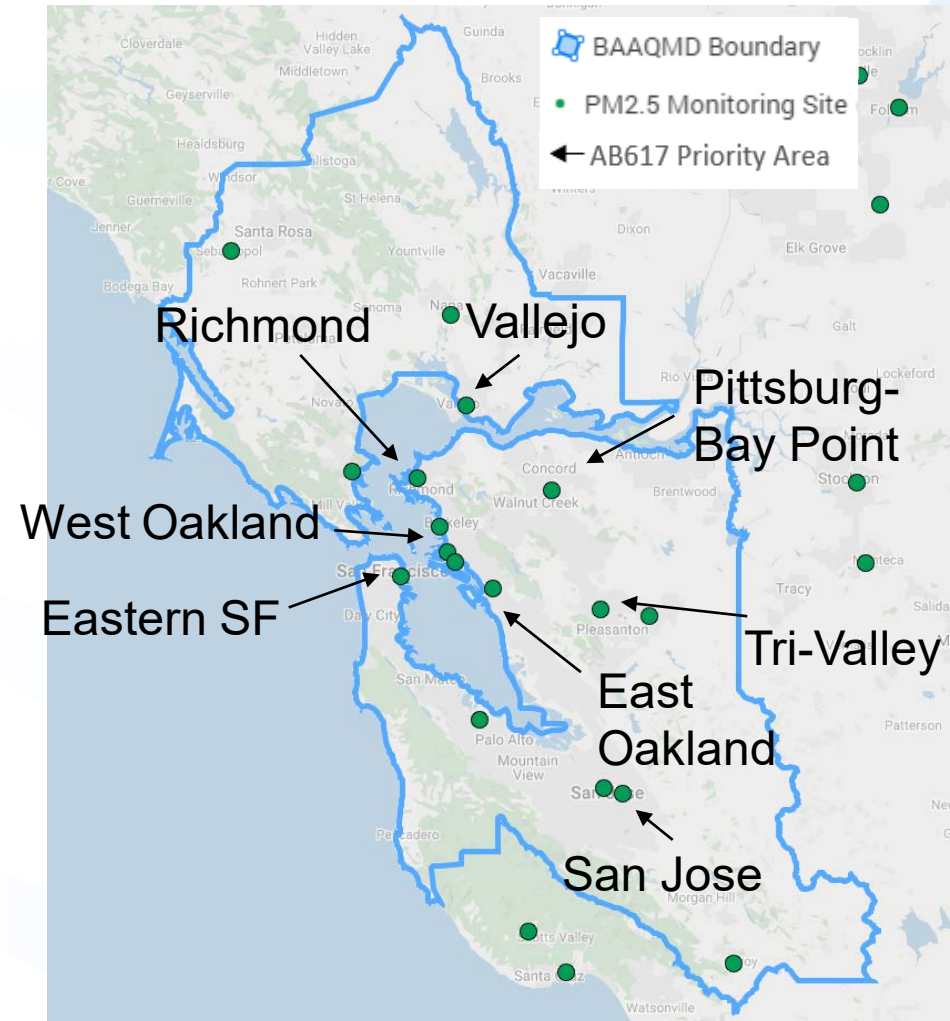
- Regional Network and Community Monitoring
 - Current capabilities
 - New developments
- What does the data show?
 - Ultrafine particles
 - Wildfire incidents
- Looking ahead
 - How could data be used
 - Options to strengthen air quality monitoring

Combining Monitoring Strategies for Multiple Objectives

Network	Measurements	Network Objectives
Regional Network	<ul style="list-style-type: none"> - PM_{2.5} and PM₁₀ Mass 	<ul style="list-style-type: none"> - Comparison with health-based standards - Public information - Track long-term trends - Assess out of area transport
Special Projects (fixed site, portable, or mobile)	<ul style="list-style-type: none"> - PM size distribution - PM speciation - UFP - Black Carbon 	<ul style="list-style-type: none"> - Source identification - Assessment of specific emission sources - Characterization of near-road environments
Sensor Networks (mobile or fixed)	<ul style="list-style-type: none"> - PM Mass - Particle Count 	<ul style="list-style-type: none"> - More challenging to interpret due to higher levels of uncertainty - Public education - Personal exposure - Identification of hot-spots - Comparative assessment of local air quality - Tracking high PM episodes

Integrated PM Network Assessment (to be completed by July 2020)

- Evaluate PM measurement network to recommend improvements with available resources
- Address existing requirements and goals
 - Federal and state requirements
 - Understand criteria pollutant levels
- Strengthen network to address gaps
 - Incorporate multiple monitoring approaches
 - Support community air monitoring activities
 - Provide data to support other Air District activities





BAY AREA
AIR QUALITY
MANAGEMENT
DISTRICT

Update on Particulate Matter (PM) Air District Work: Air District Grant Programs Overview

**Karen Schkolnick
Strategic Incentives Division Director**

**Advisory Council Meeting
December 9, 2019**



Overview

- Background
- Grants Overview and Priorities
 - Project Evaluation
 - Eligible Projects
- Supporting Air District Initiatives
- Results and Highlights
- Next Steps

Background



**Monitoring
Planning
Regulations &
Enforcement**

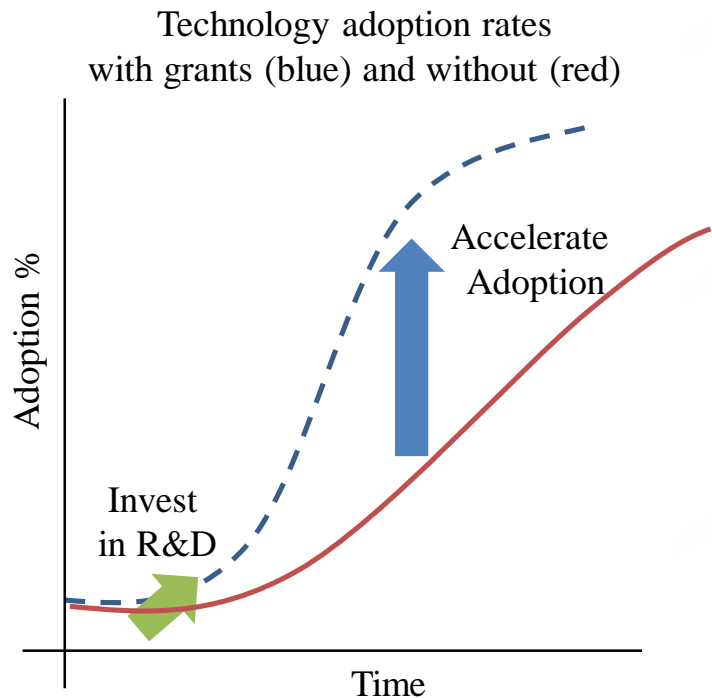


**Education
&
Outreach**



**Grants
&
Loans**

Grants Overview and Priorities



- Cost-effective air quality and climate protection benefits
- Accelerated adoption of cleanest commercially available technologies and investments in R&D
- Expedited emissions reductions in disproportionately impacted communities



Project Evaluation

Cost-Effectiveness (CE)

$$CE = \frac{\text{Funds Awarded}}{\text{Tons of } NO_x + ROG + (PM_{10} \times 20) \text{ reduced}}$$

CE* estimates *quantifiable*,

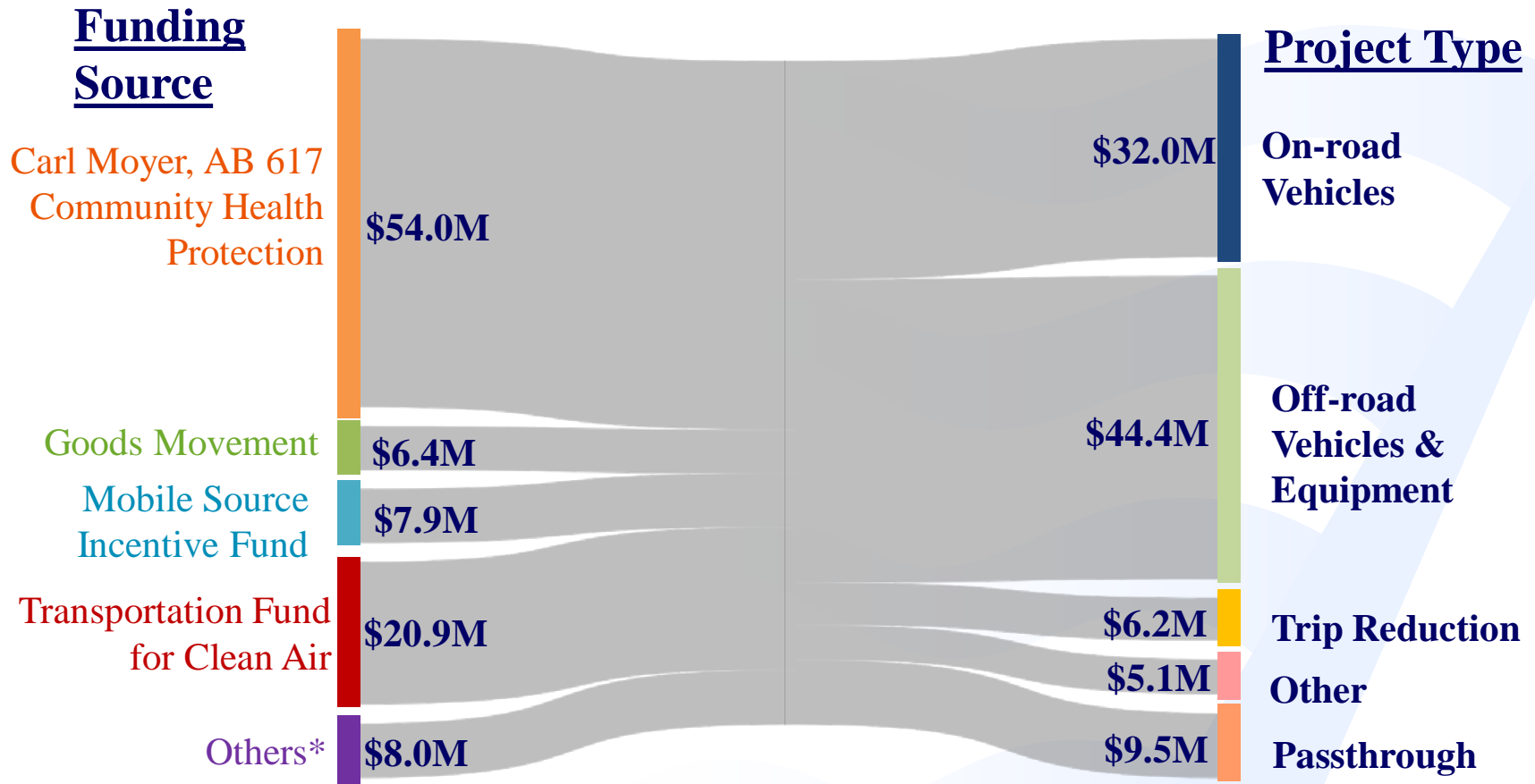
verifiable,

and surplus lifetime emission reductions

*CE formula is provided by CARB Carl Moyer Program Guidelines



>\$97M Awarded in 2018 to Eligible Projects



* Other funding sources include U.S. EPA's DERA, California Climate Investments, & Air District's general fund

Eligible Projects

On-road Vehicles

\$32.0M

On-road Vehicles

Cars & Charging Stations



Trucks



Buses





Eligible Projects

Off-road Vehicles & Equipment

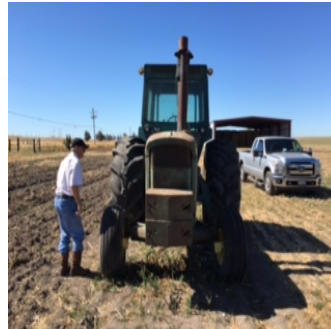
\$44.4M

Off-road
Vehicles
And
Equipment

**Cargo
Equipment**



**Ag
Equipment**



**Marine &
Locomotive**



**Other
Off-road**



Eligible Projects

Trip Reduction

Shuttles & Ridesharing



Pilot Services

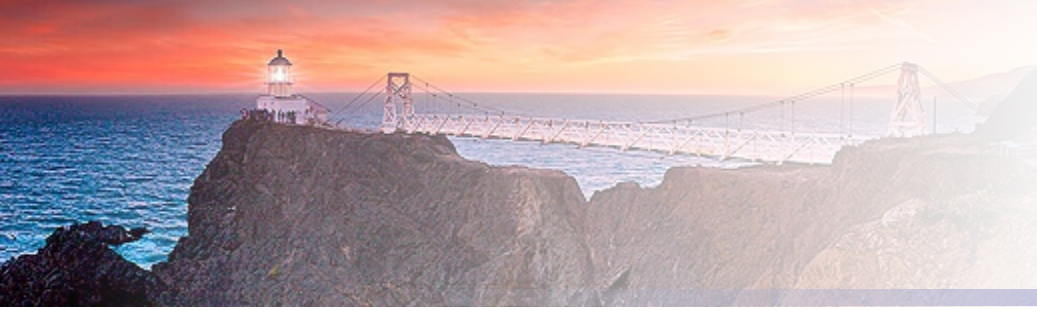


Bicycle Projects



\$6.2M

Trip Reduction



Eligible Projects Other & Passthrough

**Lawn &
Garden**



**Wood
Smoke**



**Climate
Protection**



**County
Programs**



\$5.1M

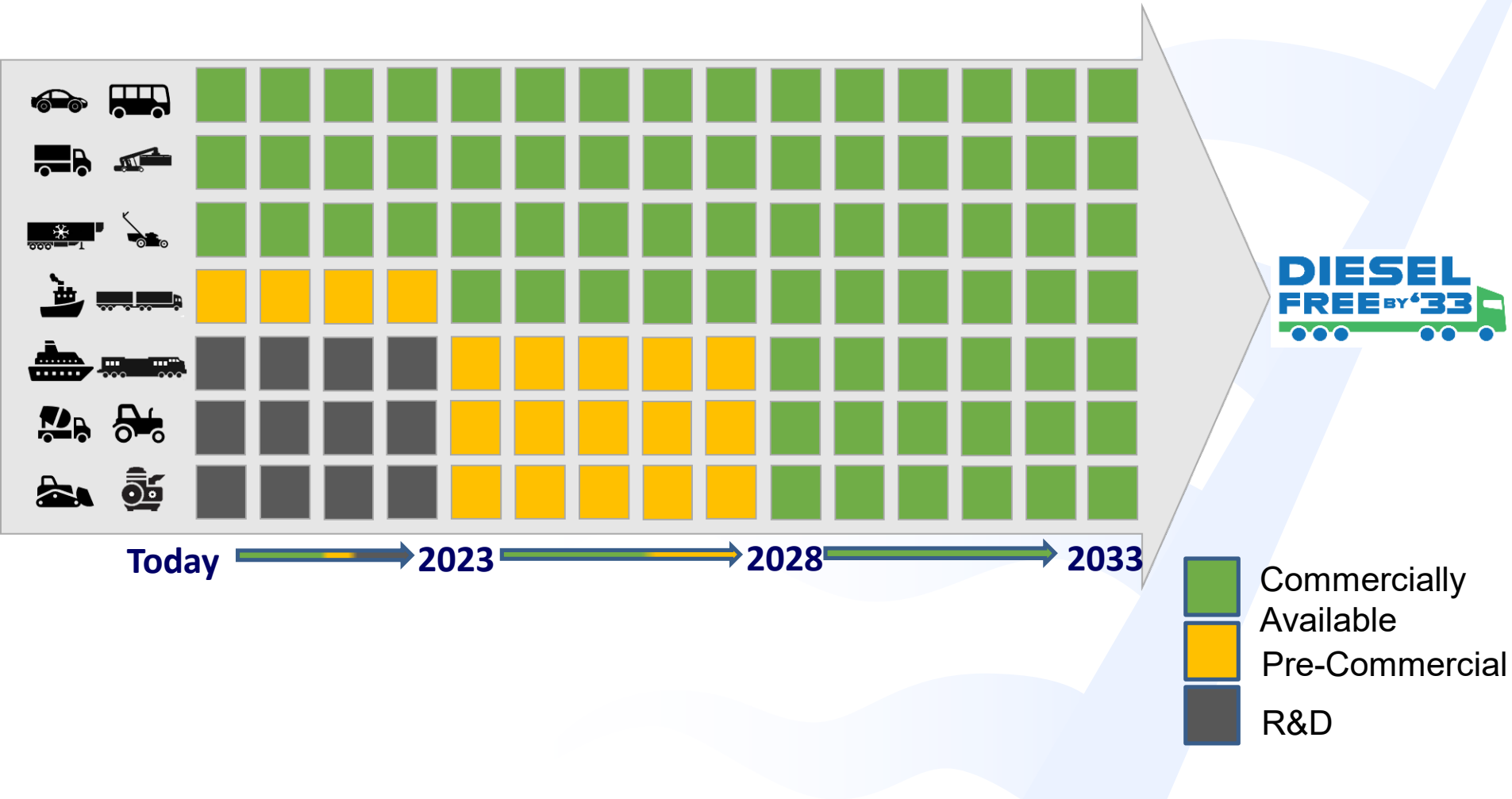
Other

\$9.5M

Passthrough

Supporting Air District Initiatives

Path to Diesel Free by '33



Supporting Air District Initiatives

Bay Area Electric Vehicle Trends & Goals

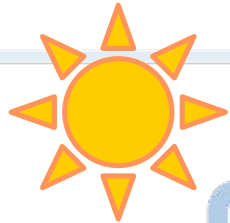
 7,750 public charging ports

Over \$15M invested to date

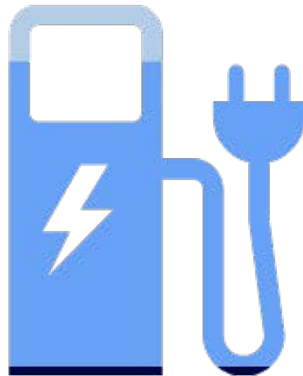
3% of the cars are EVs



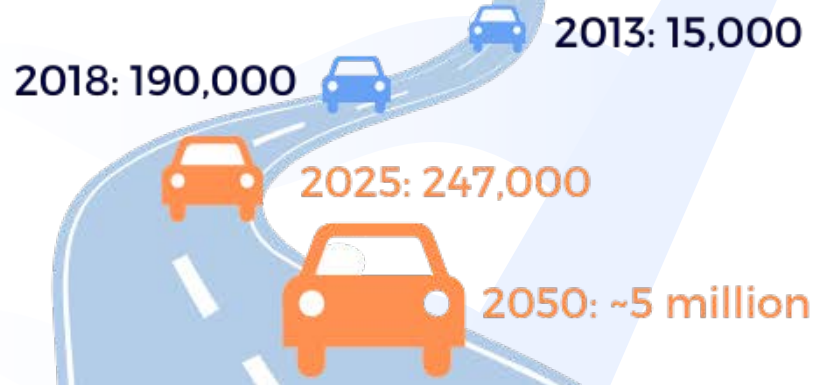
10+ EV Incentive Programs



~25% of funded stations included renewables



Progress towards our EV Adoption Goals



Supporting Air District Initiatives

Advanced Technology Demonstrations

\$2.9M to deploy 11 electric trucks & haulers for commercial delivery service



\$3M to deploy hydrogen-powered ferry for passenger service



Supporting Air District Initiatives

Early Emissions Reductions at Port of Oakland

Equipment Type	*DPM Inventory (tons)	
	2005	2017
Oceangoing Vessels	208.5	42.2
Harbor Craft	13.4	6.1
Cargo Handling Equipment	21.2	1.6
Trucks	15.9	0.3
Locomotives	2.0	0.3
Other	--	0.3
Total	261	51

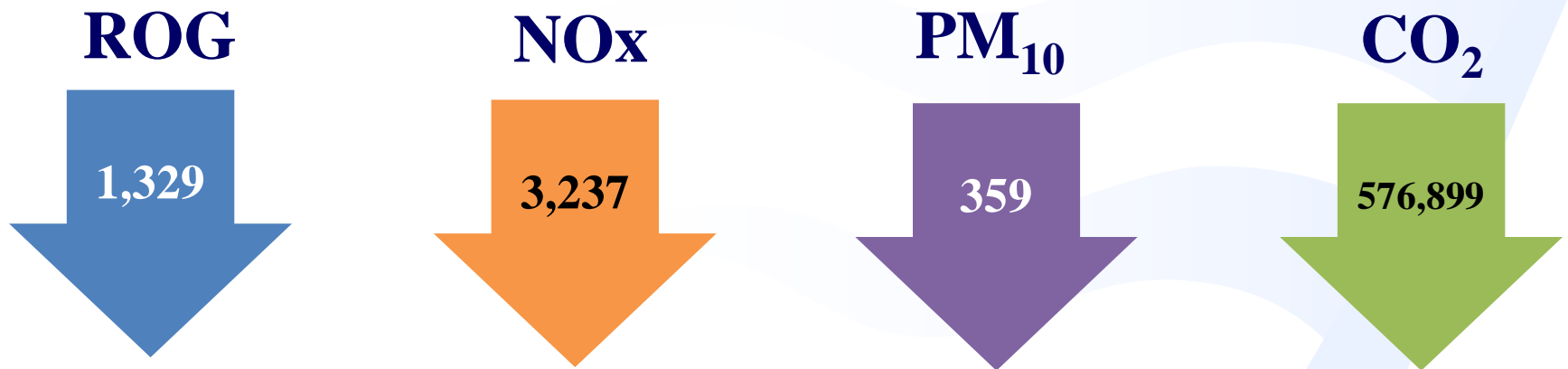
>\$100M in grants invested at Port of Oakland including:

- Retrofitted/replaced <1,900 drayage trucks
- Installed shorepower at 14 berths
- Replaced >1,090 on-road trucks

*Diesel Particulate Matter

Results and Highlights

Regionwide Cumulative Emissions Reduced (tons) Since 2015



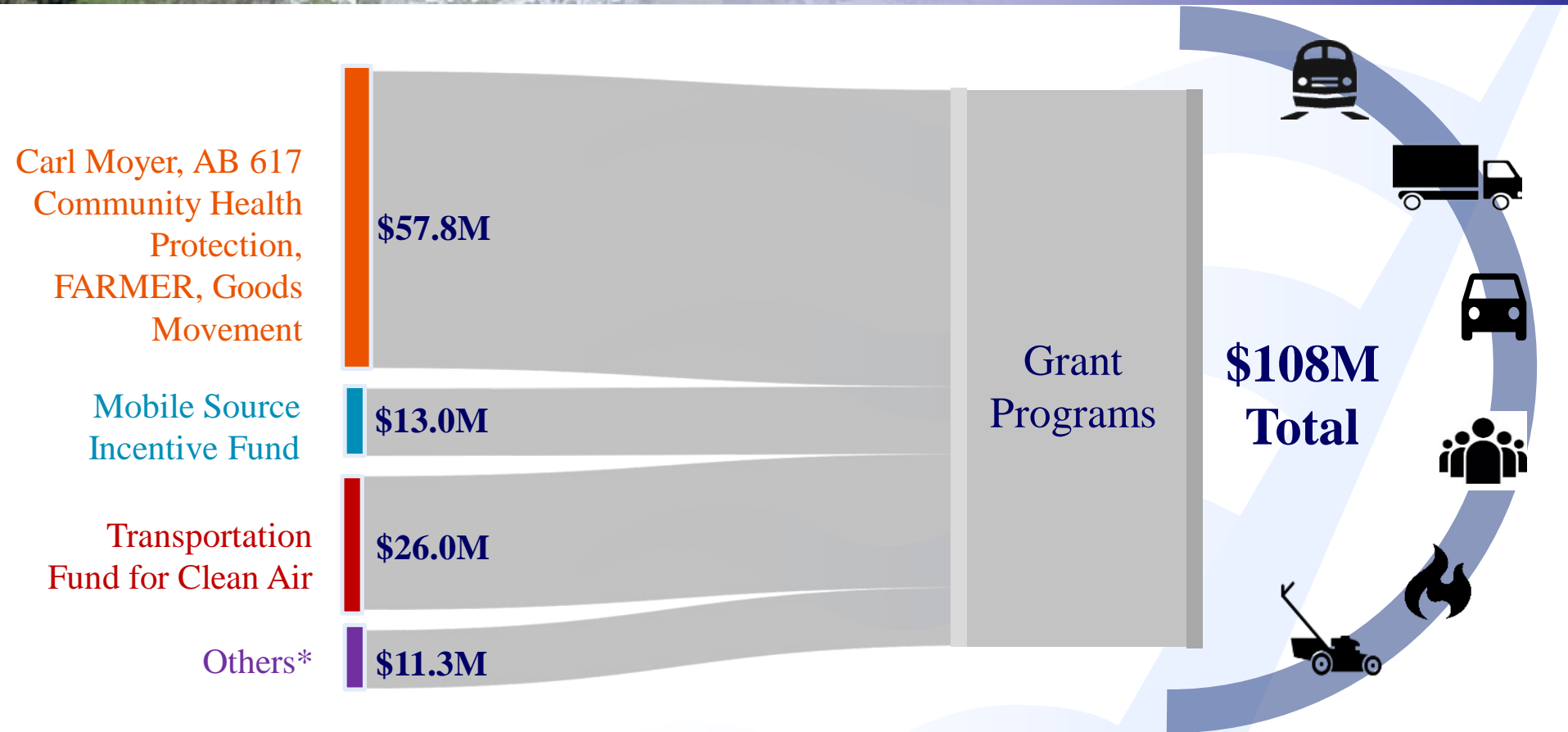
Highlights 2015 - 2019

- 1,000+ EV charging stations
- ~40 miles of bikeways
- 1,200+ woodstoves and fireplaces
- >100 ZE transit and school buses

**53% of funds
in CARE areas**

Next Steps

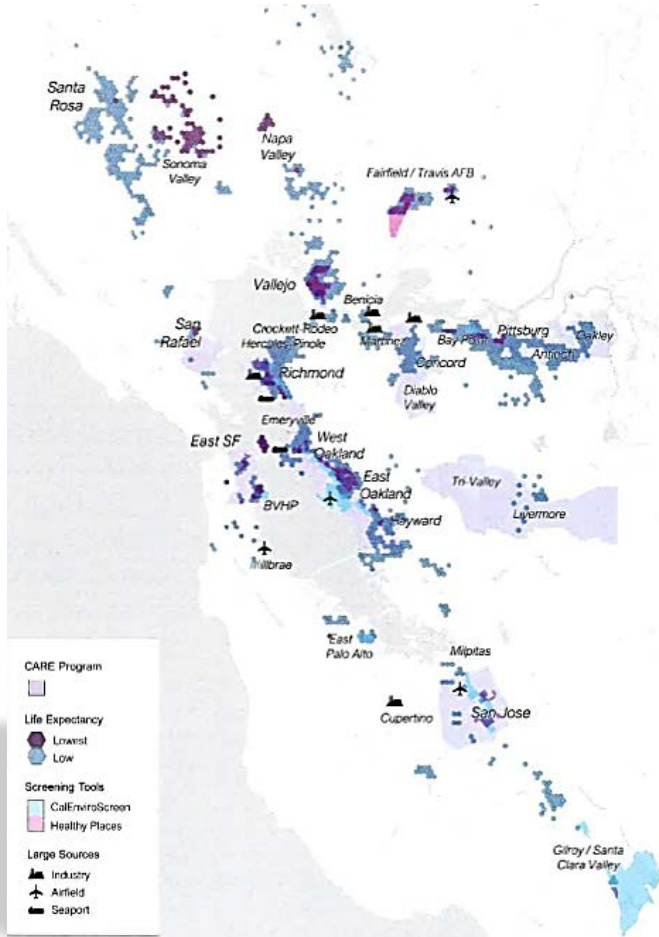
Incentive Revenues for 2020 (in millions)



* Others include Clean Cars for All and Climate Tech Finance (loan guarantee)

Next Steps

New & Expanded Grant Programs



- Secure new sources of funding
- Expand eligibility and initiate new programs
 - Expediting public health benefits in disproportionately impacted areas
 - Prioritizing programs that provide co-benefits

Particulate Matter Exposure CARB Health Research and Rule

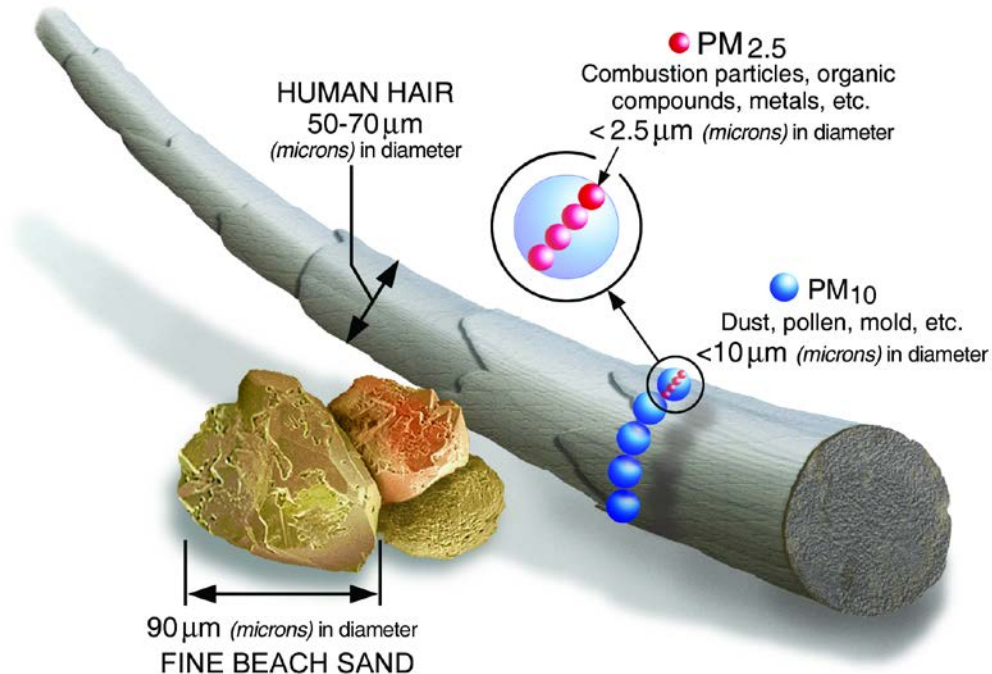
Álvaro Alvarado
California Air Resources Board
December 9, 2019

PM Exposure is an Important Public Health Concern

- Why are we concerned about PM?
 - Lots of evidence for health impacts
- If PM_{2.5} ↓ to background levels, could prevent (annually) about:
 - 7,200 premature deaths
 - 1,900 hospitalizations
 - 5,200 emergency room visits

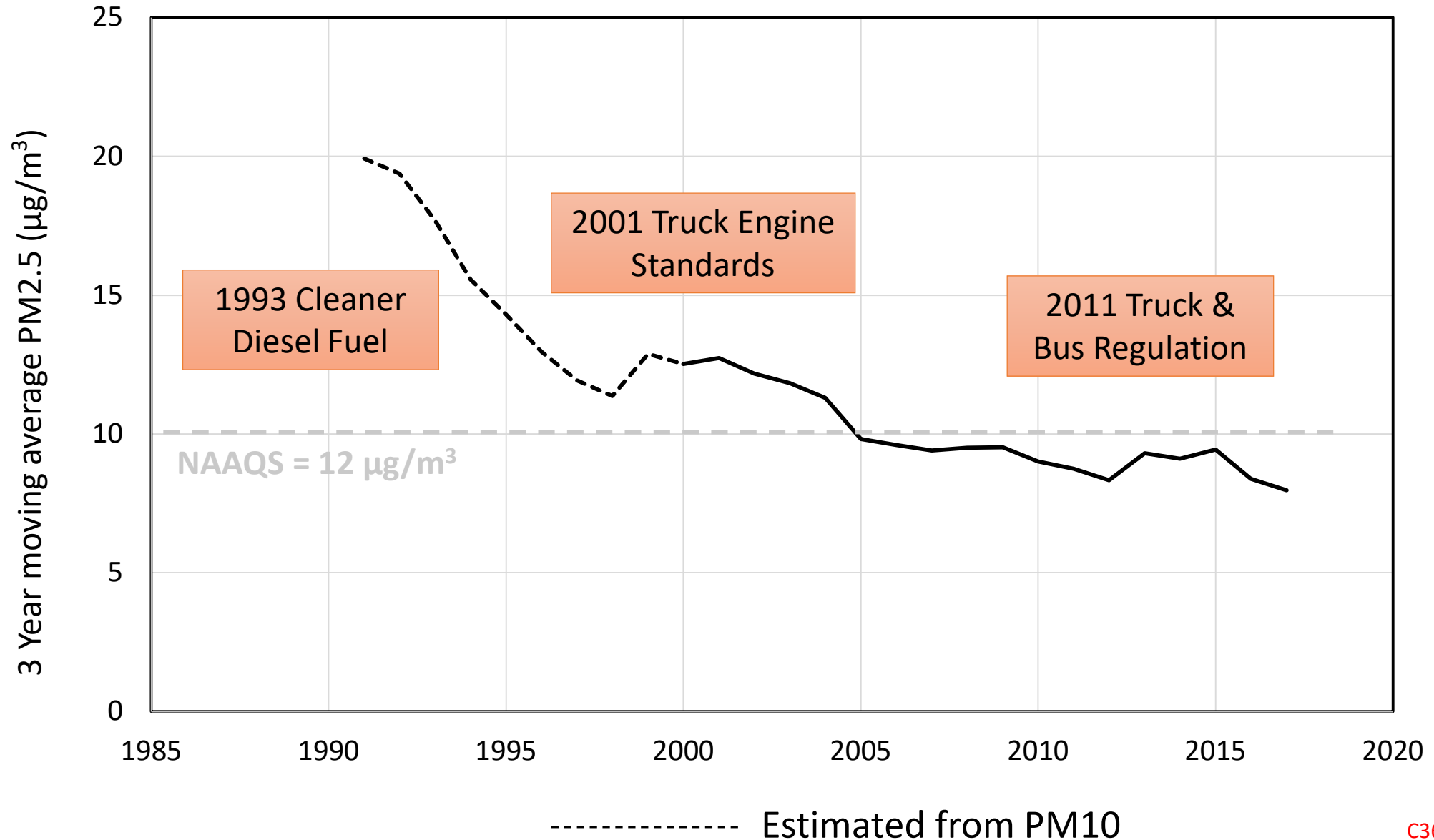


But That's Not All – Additional Evidence of PM's Negative Health Impacts



- Strong evidence for increased:
 - Asthma attacks
 - Respiratory symptoms
- Probable association with:
 - Work loss days
 - Restricted activity days
 - Adverse brain effects

PM2.5 Trend in the San Francisco Bay Area Air Basin

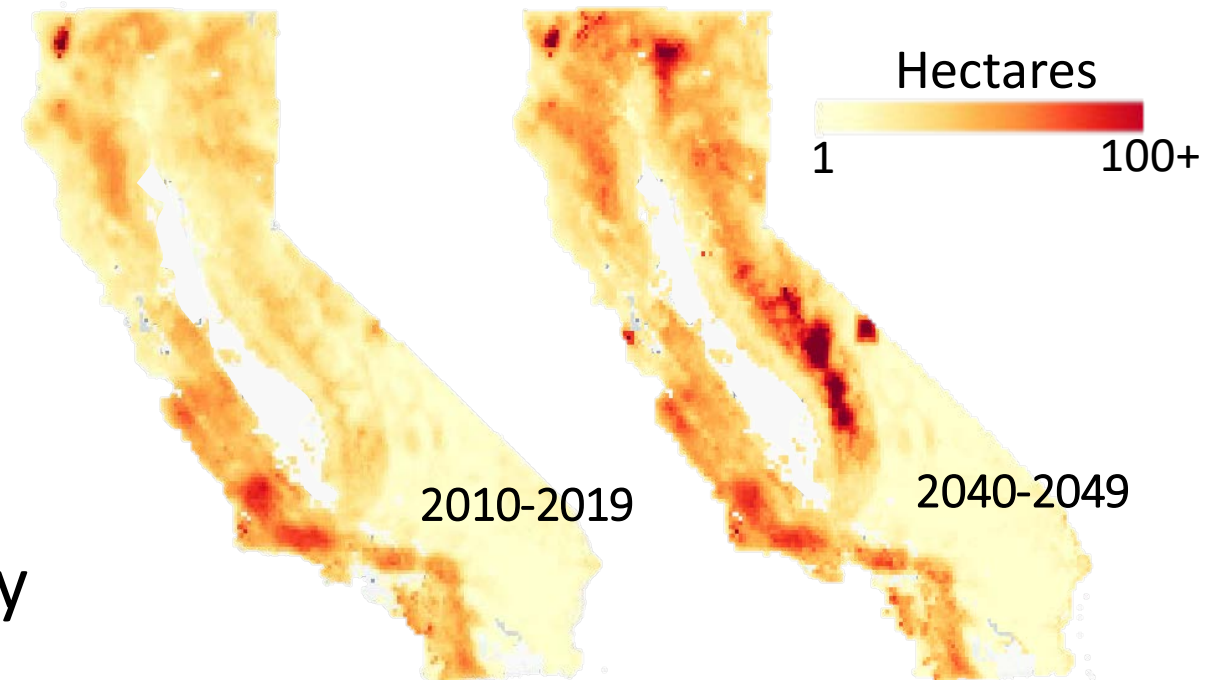


CARB's Current Efforts and New Challenges

Wildfire-related PM Exposures

- Millions of Californians exposed to wildfires in 2018
- Wildfires: more frequent & intense with climate change
- Little known about health impacts
 - PM emitted during fire; post-fire ash
 - More structure/vehicle fires
- Particular concern: children & elderly

Forecast Average Annual Area Burned



Source: CalAdapt.org

CARB Research: Wildfire Health Impacts in Rhesus Macaques

- Infant monkeys in outside enclosures unintentionally exposed to wildfire smoke (Miller, UC Davis)
- As adolescents & young adults:
 - Impaired immune function
 - Changes in lung structure
 - Reduced lung function
 - Changes passed to next generation



© CNPRC, UC Davis

CARB Research, in progress: Wildfire Emissions



- Understanding and mitigating wildfire risks (Goldstein, UC Berkeley)
 - Mobile measurements (in-house research with UC Berkeley & UC Riverside)
- NASA aircraft: investigating wildfire emissions & downwind air quality (Blake, UC Irvine)

PM from Brake & Tire Wear



BRAKE WEAR

- Successful reduction of regional PM from vehicle exhaust
- Vehicle tailpipe emissions most important regionally
- Non-tailpipe emissions may have localized importance
- Uncertainties in emissions & health impacts



TIRE/ROAD WEAR

CARB Research, in progress: Brake & Tire Wear

- Quantifying brake & tire wear emissions (Kishan, Eastern Research Group)
- Examining real-world brake & tire emissions and exposure to downwind communities (Jung, UC Riverside)
- In-house laboratory research projects
- Understanding potential health impacts (Jerrett, UCLA)



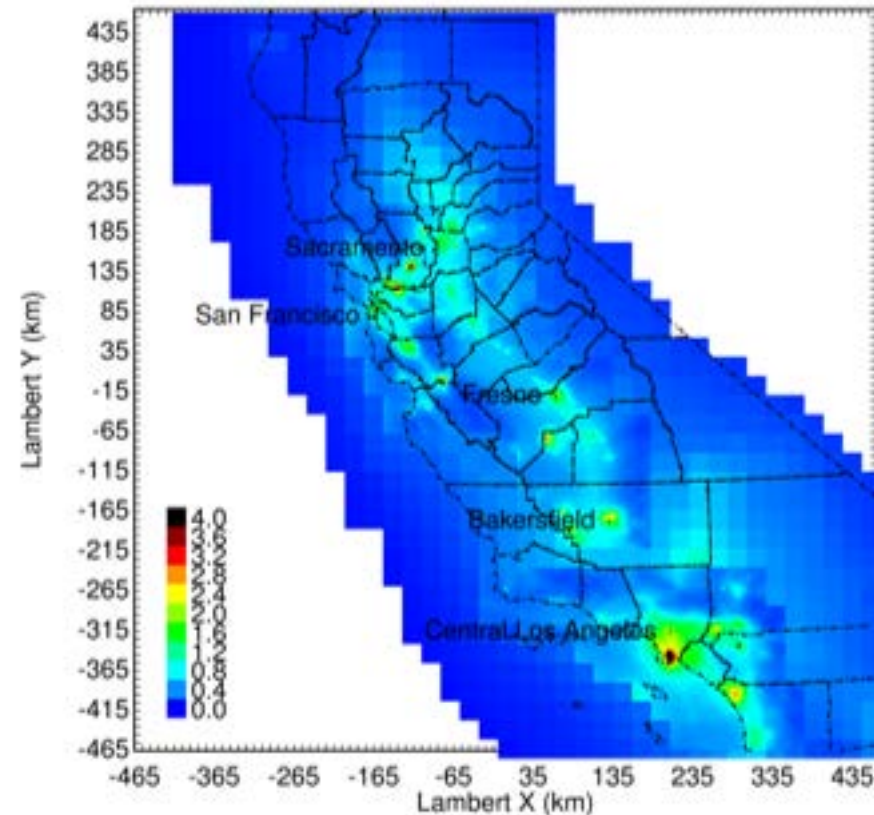
Health Risk from Ultrafine PM (UFPM)

- Potential exposure risks:
 - High numbers & chemicals attach to surface
 - Once inhaled, can go deep into lung
 - Can enter bloodstream, travel to organs
 - UFPM highly variable (space & time)
 - Sparse historical data

CARB Research: Health Effects of UFPM

- Monitoring, modeling, and health impacts of UFPM (Kleeman, UC Davis)
- Preliminary results suggest increased risk of premature death with higher exposure

Ultrafine Mass Concentration



CARB Research, in progress: Short-term PM Exposure

- White paper: reviewing short-term PM exposure impacts (Kleinman, UC Irvine; in progress)
- Air monitoring in AB 617 communities
 - Localized pollutant exposures
- Determine if need to address short-term exposures



Statewide Mobile Source Strategies Overview

Heavy Duty Trucks



Warehouses



Passenger Cars



Trains



Heavy Duty Trucks

- Advanced Clean Trucks regulation
- Heavy-duty vehicle inspection and maintenance
- Innovative Clean Transport
- Airport Shuttles
- Low NOx Omnibus Rule



Warehouses

- Freight Handbook
- Transport refrigeration unit regulations
- Drayage truck regulation amendments
- Cargo handling equipment amendment



Passenger Cars

- Advanced Clean Cars 2
- Catalytic converter theft reduction



Trains

- Reduce idling for all rail yard sources
- Potential development of regulation to reduce emissions for locomotives



Thank you



BAY AREA
AIR QUALITY
MANAGEMENT
DISTRICT

Update on Particulate Matter (PM) Air District Work:

PM Rules and Regulatory Development

**Victor Douglas
Rule Development Manager**

**Advisory Council Meeting
December 9, 2019**



Overview

- Approaches to Regulate PM
- PM Rules and Regulations
- Current and Future Efforts
 - Regional attainment
 - Localized impacts
 - Gap analysis



Regulation of PM

- **Three Ways to Regulate PM:**
 1. **Originally regulated as a Nuisance**
 - Open burning (original Reg 1)
 - Dust and aerosol (original Reg 2)
 2. **Criteria (i.e., regional)**
 3. **Toxic (i.e., local/community level)**
 - Diesel PM



Regional Approach

- Attainment of ambient air quality standards
- Control of Primary PM
 - Filterable
 - Condensable
- Control of Secondary PM
 - Oxides of Nitrogen (NO_x)
 - Sulfur Dioxide (SO₂)



PM Rules & Regulations

- Regulation 2: Permits
- Regulation 5: Open Burning
- Regulation 6: Particulate Matter
- Regulation 9: Inorganic Gaseous Pollutants
- Regulation 11: Hazardous Pollutants
- Regulation 12: Miscellaneous Standards of Performance

The background of the slide features a scenic view of the Golden Gate Bridge in San Francisco, California. The bridge's iconic orange-red towers and suspension cables are visible against a clear blue sky. In the foreground, the bridge's approach spans across a body of water, with a large, light-colored building situated on the left bank. The overall scene is bright and clear, with a blue sky and green hills in the distance.

PM Rulemaking Efforts

- 2012 – **Rule 2-2 amendments** to add New Source Review permitting requirements for PM_{2.5}
- 2012 – **New Rule 9-13** to reduce PM emissions from Portland cement kilns
- 2013 – **New Rule 6-4** and **new Rule 12-13** to reduce PM emissions from metal foundries and shredding facilities



PM Rulemaking Efforts

- 2015 – **Rule 6-3 amendments** to further reduce wood smoke from wood-burning devices
- 2016 – **New Rule 9-14** to reduce precursors of secondary PM from petroleum coke calcining operations
- 2018 – **New Regulation 6, new Rule 6-6, and Rule 6-1 amendments** to reduce PM emissions from fugitive dust sources
- 2019 – **Rule 6-3** to extend No Burn Days for the Wildfire Response Program



2018 PM Rules

- New Regulation 6 for common definitions and test methods
- New Rule 6-6 for prohibition of trackout
- Rule 6-1 amendments for general requirements and bulk material handling
- Reduce PM emissions from fugitive dust sources
- Expected emission reductions of 1.6 tpd PM_{10} , 0.2 tpd $PM_{2.5}$



Current and Future Efforts

- Continued **regional** efforts on further PM reductions (e.g., Rule 6-5: PM from FCCUs)
- Source categories and rule efforts identified in planning efforts
- Additional areas from gap analysis
 - Restaurants
 - Wood smoke
 - Indirect and magnet sources
 - PM as a toxic pollutant



Current and Future Efforts (cont.)

- To address **localized** PM issues
- Regulatory framework for site-specific localized PM impacts
- Existing localized approaches for toxics
 - Air District Rule 11-18 for Air Toxic Emissions from Existing Facilities
 - AB 2588 Air Toxic Hot Spots Program



Discussion

Questions?

Discussion Questions

Are current PM standards sufficiently health protective?

Are some species of PM more dangerous than others?

What is role of ultrafine particles (UFPs)?

Should form of target expand to account for more than just mass?

How should we include draft PM ISA's new "likely-causal" health endpoints (nervous system effects, cancer) and new more sensitive populations (children, lower socio-economic status)?

What are health impacts of high-concentration acute events (e.g., wildfires)? How should we compare them to day-to-day PM impacts?

Discussion Questions

What are major sources of PM in the Bay Area?

What PM levels exist in Bay Area? What health risks do they pose?

How much additional health benefit can be achieved?

How should we account for spatial scale of effects (i.e., regional versus local-scale impacts, including proximity to major sources)?

How should we determine which measures would most move public health needle?

Deliberation Questions

What is bullseye in clean air target? How clean is clean enough?

How will we know when we get to target? What metrics should we use to track progress?

How do we combine criteria pollutants and toxics? Cancer and non-cancer health endpoints?
Short- and long-term effects?

How can we make sure everyone is treated fairly?

How can we ensure that everyone breathes clean air?

What are most important actions that can be taken now? And, in future?

Discussion Questions (DRAFT)

Are current PM standards sufficiently health protective?

NOT SUFFICIENTLY PROTECTIVE; MORE STRINGENT STANDARDS NEEDED

Are some species of PM more dangerous than others?

QUITE POSSIBLY BUT NOT ENOUGH INFORMATION; NO PM COMPONENTS “EXONERATED” THOUGH

What is role of ultrafine particles (UFPs)?

NOT YET CLEAR, BUT TOX STUDIES OF CONCERN; NEED UFP FEDERAL REFERENCE METHOD; MORE MONITORING; EPI STUDIES NEEDED

Should PM “target” expand to account for more than just mass?

IN RESEARCH, ABSOLUTELY; IN REGULATION, TOO SOON, UNLESS HIGHLY RISK-AVERSE

How should we include draft PM ISA’s new “likely-causal” health endpoints (nervous system effects, cancer) and new more sensitive populations (children, lower socio-economic status)?

STRONGER EVIDENCE, NEW HEALTH EFFECTS; GROWING RECOGNITION OF “AT RISK” GROUPS (E.G., CHILDREN AND LOW SES); NEED TO CONSIDER

What are health impacts of high-concentration acute events (e.g., wildfires)? How should we compare them to day-to-day PM impacts?

NOT WELL-KNOWN SCIENTIFICALLY, BUT OF CONCERN; DATA ON SUB-DAILY EXPOSURES TOO LIMITED AS YET; POTENTIALLY SERIOUS EFFECTS REPORTED IN EARLY STUDIES; NEW STUDIES ONGOING; MORE RESEARCH NEEDED

Discussion Questions (DRAFT)

What are major sources of PM in the Bay Area?

**WEST OAKLAND: PM2.5, TOP 3 – PORT (17%), STREET (17%), HIGHWAY (16%);
DIESEL PM, TOP 3 – PORT (57%), STREET (7%), HIGHWAY (8%)**

What PM levels exist in Bay Area? What health risks do they pose?

**WEST OAKLAND: PM2.5 = 8.7 ug/m3 (ALL SOURCES, AVERAGE), LOCAL SOURCES = 1.5 to 2.2 ug/m3 (BY NEIGHBORHOOD);
DIESEL PM = 0.7 ug/m3 (AVERAGE);
HYPER-LOCAL HOT SPOTS COULD BE HIGHER**

How much additional health benefit can be achieved?

REDUCING ANNUAL PM2.5 FROM 12 ug/m3 TO 10 ug/m3 COULD REDUCE RISK BY 10-15%; THOUSANDS FEWER DEATHS IN U.S. EACH YEAR

How should we account for spatial scale of effects (i.e., regional versus local-scale impacts, including proximity to major sources)?

**SPATIAL SCALE IMPORTANT; REGIONAL- VS. LOCAL- VS. HYPER-LOCAL-SCALE IMPACTS
WEST OAKLAND: PM2.5 CONCENTRATION – OVERALL, 80% FROM REGIONAL SOURCES, 20% FROM LOCAL SOURCES;
DIESEL PM CONCENTRATION – OVERALL, 40% FROM REGIONAL SOURCES, 60% FROM LOCAL SOURCES; HYPER-LOCALIZED HOT SPOTS COULD BE HIGHER**

How should we determine which measures would most move public health needle?

NEED MORE SCIENCE, AND NEED TO ACT NOW; OPTIONS TO BE DETERMINED; DISTRICT STAFF TO IDENTIFY

Deliberation Questions (DRAFT)

What is bullseye in clean air target? How clean is clean enough?

XXX

How will we know when we get to target? What metrics should we use to track progress?

XXX

How do we combine criteria pollutants and toxics? Cancer and non-cancer health endpoints? Short- and long-term effects?

XXX

How can we make sure everyone is treated fairly?

XXX

How can we ensure that everyone breathes clean air?

XXX

What are most important actions that can be taken now? And, in future?

XXX

SUMMARY: Community Particulate Matter Discussion February 27, 2020

NOTE: A full transcript of the event is available from the stenographer. This summary aims to capture key themes in advance of the submission date for background materials for the next PM Symposium.

Overview

Community members, grassroots organization leaders, and Air District staff members met at the Bobby Bowens Center in Richmond on the evening of February 27, 2020 to gather community input on particulate matter (PM) impacts, monitoring, and regulatory efforts. The event was organized by a Design Team of community leaders with assistance from Elinor Mattern of the Air District's Community Engagement Section. Approximately 30 people attended to express their concerns regarding PM, its sources, and its health effects.

Input from community members centered on the following issues:

Localized PM data availability

- Desire for data beyond West Oakland
- Desire for real-time, continuous, publicly accessible localized monitoring
- Consolidating/sharing community-collected data (e.g. PurpleAir)

Toxicity of different PM species

- Concerns regarding severity of problems from refineries and other permitted sources (e.g. cement plant, concrete crushers, metal processing facilities)
- Skepticism regarding wood burning as a major driver of health impacts

Lack of observable results from prior rulemaking

- 2017 Clean Air Plan
- Crude slate inventory
- General enforceability issues

Potential for problems to worsen

- Issuance of new permits
- Emerging indoor air concerns (e.g. vapor intrusion) beyond the scope of the Air District
- Climate impacts
- Lengthy time horizon prior to implementation (e.g. diesel PM rules took 10 years)

This summary provides a brief background on the event. Additional details regarding these community concerns and the Air District's clarifications in reply are noted in the transcript.

Background

The February Community Discussion in Richmond was part of a series of Bay Area events focused on health effects of PM. This series began in October of 2019 and will culminate in a set of findings from the Air District's Advisory Council to be delivered to the Air District Board. The Community Discussion preceded a planned symposium that was to be held in Oakland, originally scheduled for March 24th, 2020, but postponed due to COVID-19, at which representatives from local community organizations would present to the Advisory Council regarding local PM efforts, needs, and priorities. The purpose of the Community Discussion was to gather additional community input and engagement prior to that next Symposium.

The following community leaders worked together to organize the event with assistance from Elinor Mattern of the Air District's Community Engagement Section:

- Katherine Funes - New Voices Are Rising
- Richard Gray - 350 Marin
- Jed Holtzman - 350 Bay Area
- Ashley McClure - California Climate Health Now
- Steve Nadel - Sunflower Alliance
- Ken Szutu - Vallejo Citizen Air Monitoring Network
- LaDonna Williams - All Positives Possible

A list of community members who attended the event is provided in the attached Appendix, along with information on the missions of the organizations with which they are affiliated.

Structure

The gathering began at 5pm with informal sharing of a meal, followed by introductions from discussion facilitators Azibuike Akaba (Senior Public Information Officer, Air District) and Laura Neish (Executive Director, 350 Bay Area). Jed Holtzman (350 Bay Area) also offered welcoming remarks. Brief presentations by Air District staff preceded the discussion portion of the event:

- Goals of the PM Symposium Series (Greg Nudd)
- Major Sources of Fine Particulate Matter (Phil Martien)
- Current & Potential Rules to Reduce PM (Jacob Finkle)
- Policy Approaches for Particulate Matter (Victor Douglas)

Attendees asked questions and contributed comments following each presentation in addition to participating in the discussion portion of the gathering. Facilitators concluded the event at 8pm. The content of these exchanges is summarized thematically in the following section. Details on Air District presentations are omitted as this information is also being shared in the PM Symposia and details are recorded in the transcript of the Community Discussion.

Key Concerns Expressed by Community Members and Air District Replies

Localized PM data availability

“I think the public needs to have more access to what is going on.”

Desire for data beyond West Oakland. Several community members expressed frustration with the repeated presentation of West Oakland information, as such information has not been provided for other areas. For some community members, this emphasis on West Oakland felt “disrespectful” to other communities.

Air District reply: The localized analysis piloted in West Oakland is a very new approach, so it requires cautious expansion. Vehicle-mounted monitors are in the process of collecting data for the entire Bay Area. Richmond data is now available. Information for other communities will be rolled out over the next couple of years.

Desire for real-time, continuous, publicly accessible localized monitoring. Community members seek the capability to access “readouts” in real time to determine local air quality, particularly in the presence of unusual odors or flares. Concerns were expressed regarding current monitoring accuracy, with the example given of normal readings following permitted-facility accidents. An additional concern was the perception that polluters are not required to pay for monitoring: “Currently all this cost falls onto the community and we don’t have the money. And if we don’t have the money we don’t have the monitoring and the business pollutes freely.”

Air District reply: Monitoring is continuous and publicly accessible but not in real time. The Air District hopes to move toward real-time monitoring, but presently both sample analysis and data analysis create lags. Permitted facilities are required to conduct and pay for their own monitoring, and the Air District performs tests to confirm the accuracy of that monitoring.

Consolidating/sharing community-collected data (e.g. PurpleAir). As organizations and community members have begun collecting air monitoring data themselves using technology such as PurpleAir, they are seeking a means of consolidating and sharing those data. Steve Nadel of the Sunflower Alliance asked whether the Air District is working on that effort.

Air District reply: There is a new third-party “Bay Air Center” (independent of the Air District) that will provide technical support for monitor selection and siting. The California Air Resources Board has agreed to centralize air quality sensor data through their grant program. This process is likely to be challenging.

Toxicity of different PM species

“Just presenting the percentages [from different sources] doesn’t give the full picture of toxicity. Not all particulate matter is created equal.”

Concerns regarding higher severity of PM health effects from permitted sources. Depiction of PM contributions from different sources as percentages of a total raised concerns for attendees who stated that some types of PM are more toxic than others. Many comments in the meeting focused on permitted sources, including oil refineries, metal processing facilities, and concrete crushers. Community representatives want to understand where the “fault lines” lie in terms of permitted facility PM fallout — for example, a community may be downwind of a refinery yet not be considered a “refinery community” depending on where boundaries are drawn.

Air District reply: Compounds that are known to be toxic (e.g. toxic metals) are independently tracked. However, there is insufficient information regarding the toxicity of undifferentiated PM, which is why the Air District takes a precautionary approach assuming all PM to be highly hazardous. Regarding impacts from permitted facilities, studies are currently being conducted by the Air District to better understand PM emissions from refineries and to track exposures from local sources of PM in disproportionately burdened communities. Additionally, new rules regarding fluidized catalytic cracking units are in the final stages of development. With respect to the East Oakland AB&I metal foundry, the Air District is involved in resolving issues with Rules 11-18 and 12-13 regarding air toxics and PM.

Skepticism regarding wood burning as a major driver of health impacts. A significant amount of skepticism was expressed by community members regarding wood burning as a leading PM health issue. Air District measurement and monitoring methods were questioned. There was apparent frustration with the implied equating of wood smoke to refinery smoke.

Note: A community member who was not able to be present at the gathering, Richard Gray of 350 Bay Area, stated upon reading the transcript that in the San Geronimo area where he lives residential wood burning does have a substantial negative impact on air quality. He expressed that certain weather patterns can cause this wood smoke to remain in the immediate area rather than dissipate, and that problems associated with that smoke exposure have prompted numerous residents to relocate.

Air District reply: Data collection on wood burning involves not only surveys and modeling but also filter analysis to reveal the components of localized PM: “We can tell what is on those filters and what fraction is from wood burning.” However, it is expected that wood burning is more prevalent in some areas than others, which will be clarified in the forthcoming community-level studies. Current science indicates that wood smoke is highly toxic.

Lack of observable results from prior rulemaking

“It seems like implementation is a problem.”

2017 Clean Air Plan. Jed Holtzman of 350 Bay Area stated that many of the solutions that the Air District is currently presenting were already in the 2017 Clean Air Plan and asked what institutional constraints are preventing implementation. He also described an existing rule

requiring facilities to conduct health impact assessments and stated that two and a half years after the rule had been developed this is still not happening.

Air District reply: New approaches are being implemented to speed up the process. This PM Symposium Series is designed to ensure that the full impact of PM — as reflected in the science and the community — is clear to decision makers. In addition to the health costs, the economic costs of PM are being calculated in order to further incentivize action. Additionally, the Air District is pursuing innovative means of clarifying jurisdiction for local sources of PM, such as “magnet sources” like warehouses that attract truck traffic.

Crude slate inventory. Rule 12-15, requiring accurate crude inventories, was brought up by Shoshana Wechsler of 350 Bay Area/Sunflower Alliance, who asked for the status of this data.

Air District reply: There have been some reporting difficulties because legal constraints prevented the Air District from specifying formats for data collection. A means of requiring standardized reporting has now been identified and this information will soon be available.

General enforceability issues. Several issues with enforceability were raised, such as lack of moisture content measurement at construction sites to limit dust, and citations of violations being limited to “visibility” issues following fires at permitted facilities. Ken Szutu of the Vallejo Citizen Air Monitoring Network suggested that perhaps rather than arranging community meetings with the Air District’s rulemaking teams, these meetings should be centered on the departments responsible for enforcement.

Air District reply: The Air District does not have “police powers.” The enforcement process is carried out by the District Attorney. The Air District strives to work collaboratively with permitted facilities to ensure compliance.

Potential for problems to worsen

“You can’t stop the cold air coming in if you close a window on one end and then open a different one on the other.”

New permits continue to be issued. Much attendee support was expressed for a comment from LaDonna Williams of All Positives Possible that, despite all the discussion about reducing emissions, the Air District continues to issue permits to new sources.

Air District reply: The Air District is statutorily obligated to issue permits. However, the aim is to put the brakes on emissions in areas that are already overburdened. The Air District is developing an approach intended to consider existing PM exposures in the community in order to ensure that burden is not increased.

Emerging indoor air concerns. Residents are experiencing problems with toxic vapor intrusion of polychlorinated biphenyl (PCB) and trichlorobenzene (TCB) compounds in their water delivery systems. They asked how the Air District can help.

Air District reply: Although household indoor air is not within its authority, the Air District is seeking to collaborate with the Water Control Board and will be involved in a multi-agency workshop to try to speed resolution of this problem.

Climate impacts. A community member inquired about the connection between the health impacts under discussion and the public health threat of the climate crisis.

Air District reply: The 2017 Clean Air Plan demonstrates the linkages, with one of its three pillars focusing on health.

Lengthy time horizon prior to changes being implemented. Citing the example of diesel PM rulemaking taking 10 years, concern was expressed that the present process may be many years away from producing meaningful change: “How do we compress that?”

Air District reply: With the Board’s buy-in, we can start working on elements of our strategy without having to wait years. We are working to compress that timeline.

APPENDIX - Attendee List for Community Particulate Matter Discussion – 2/27/2020

Organization	Representative(s) Attending (+ Organizational Role)	Website	Notes on Organization Mission (based on websites)
350 Bay Area	Jed Holtzman (Senior Policy Analyst)	https://350bayarea.org/	Bay Area organization supporting policies that promote clean energy, eliminate fossil fuels, and facilitate just and socially equitable solutions to ensure a livable planet for future generations.
350 Contra Costa	Jackie García	https://350bayarea.org/350contracosta	Contra Costa team of 350 Bay Area (see above)
All Positives Possible	LaDonna Williams (Programs Director), Pat Dodson and Janniece Murray	https://www.guidestar.org/profile/61-1588146	East Bay nonprofit supporting efforts of low-income communities of color to confront crises of environmental health and injustice.
Bayview Hunters Point Resident	Raymond Thompkins	N/A	N/A
California Climate Health Now	Ashley McClure, Cynthia Carmichael	https://www.climatehealthnow.org/	California physicians and health professionals “who recognize climate change as the public health and equity emergency of our lifetimes.”
Communities for a Better Environment	Andrés Soto	http://www.cbecal.org/	California environmental justice organization focused on global climate issues and local transformation toward sustainable communities. Provides organizing skills, leadership training, and scientific and legal assistance.
Groundwork Richmond	Jen Fong	http://www.groundworkrichmond.org/	Richmond environmental organization helping youth develop leadership potential through science, technology, engineering, arts, and math.
Higher Ground Neighborhood Development Corp.	Khariyyah Shabazz (Assistant Programmatic Director) and Reggie Archie	http://www.highergroundndc.com/	Oakland-based neighborhood development corporation focused on youth.
Interfaith Climate Action Network of Contra Costa County	Will McGarvey,	http://www.ican-cc.org/	Contra Costa County organization educating faith and non-faith communities about mitigating climate change and providing advocacy on their behalf to ensure oppressed community voices are heard by policymakers, industries, and other organizations.

New Voices Are Rising/Rose Foundation	Katherine Funes (Youth Engagement Co-Director) & 3 youth	https://rosefdn.org/new-voices	Oakland-based project seeking to increase civic participation within underrepresented communities, increase young people's commitment to environmental justice, and reduce air and water pollution in the SF Bay Area. Part of the Rose Foundation for Communities and the Environment.
No Coal in Oakland	Misao Brown	https://nocoalinoakland.info/	Oakland-based organization campaigning to stop the threat of coal being transported by rail into Oakland for export overseas.
No Coal in Richmond	Jaime Perez	https://ncir.weebly.com/	Richmond-based organization supporting phase-out of coal and pet coke operations to protect health.
Physicians for Social Responsibility	Robert Gould (President), Jeff Ritterman (Vice President of Board of Directors)	http://sfbaypsr.org/	Bay Area chapter of organization seeking to promote public policies that protect human health from climate change and environmental degradation as well as nuclear war and other weapons of mass destruction, gun violence, and other social injustices.
Rodeo Citizens Association	Janet Pygeorge, Charles Davidsen	https://rodeocitizensassociation.org/	Non-profit organization devoted to issues concerning the unincorporated community of Rodeo, California. Their primary purpose is to address local concerns to health, safety and the environment.
Sierra Club Bay Chapter	Dave McCoard (Co-Chair of Energy Committee)	https://www.sierraclub.org/san-francisco-bay	SF Bay Area chapter of national grassroots environmental organization. Chapter has nearly 40,000 members. Issues include energy and climate, sustainable communities, parks and open space, environmental justice, water, and wilderness and wildlife.
Sunflower Alliance	Steve Nadel and Shoshana Wechsler	https://www.sunflower-alliance.org/	Bay Area citizen group focused on halting fossil fuel production and transport, particularly in the East Bay.
Vallejo Citizen Air Monitoring Network	Ken Szutu (Chair)	http://citizenairmonitoringnetwork.org/vallejo/	Vallejo citizen group collecting and publicizing local air quality data to enable rapid response to air quality problems.
Youth vs Apocalypse	2 youth	http://youthvsapocalypse.org/	Bay Area group of diverse young climate justice activists (ages 10-18) working to lift the voices of youth, in particular youth of color, and fight for a livable climate and an equitable, sustainable, and just world through policy advocacy. Supported by 350 Bay Area.

Community Reflections from Feb. 27 Community Summit on PM

Jed Holtzman, MEM
Senior Policy Analyst



on behalf of the
BAAQMD Network



Intro/Context

The federal government is moving backwards on PM regulation.

California must lead the nation—and as usual, we here must lead the state—in reducing PM emissions to protect both public health and public coffers.

The current coronavirus pandemic highlights the necessity to prioritize steep PM reductions—particularly in frontline, overburdened, and disadvantaged communities, and those that have experienced environmental injustice and racism.

Intro/Context

Communities' excess exposure to PM makes them significantly more vulnerable to the impacts of SARS-CoV-2 and the other health and environmental challenges that will be expected with ongoing climate warming.

We request that the Advisory Council make the strongest possible statement to the Board on the need for aggressive Air District action to reduce PM to the maximum extent feasible, in order to protect public health.

We need BAAQMD action on all cylinders, we need robust rulemaking, and we need it yesterday. Delay translates directly into death and suffering of Bay Area residents, at the rate of thousands per year.

Regional/Local

To even hope to meet a health-protective PM target, we need to attack it from both directions, using both regional AND local approaches.

Regional Approach

There is no safe level of PM exposure, the concentration-response curve is linear, and we could keep saving lives by further reducing PM emissions.

The Air District should set the lowest PM standard available to protect public health given the overwhelming data. If this requires coordinating with ARB and the legislature to take leadership, it won't be the first time.

Setting a truly health-protective PM standard in the Bay Area will provide the impetus for an effective PM Reduction Plan, with all feasible measures needed to achieve attainment of the standard.

Local Approach

For locally significant sources of PM, staff is proposing to employ a toxic health risk approach.

Given the incredible failure with the implementation of Rule 11-18 on toxic risk reduction, how does the District think it is going to lean this approach to handle all needed PM reductions from local stationary and magnet sources as well?

And how will those reductions come at a relevant time scale, given thousands of deaths per year of delay?

Local Approach

How can we identify problematic local sources and deal with them faster? We can't wait until all burdened communities get AB 617 designation, which is all the more unlikely now in the post-pandemic budgetary environment.

The status quo Air District process on toxics is not working and will not work on the timescale in which we need to see reductions.

So do you ramp up the HRA staff and workflow at the District by more than 10x? Or do you come up with an alternate regulatory strategy? Something must change.

Regional/Local

Whether locally or regionally, our common concerns are the strength and breadth of regulations and the speed and robustness of their implementation.

Paying to Pollute

Penalties for violations of Air District rules with any primary or secondary PM emissions impacts must be increased substantially to reflect the true costs to the Air District and public health.

Both greater penalties for violations and an augmented enforcement regime at facilities are needed to incentivize compliance and provide serious disincentives for multi-billion dollar companies to pollute.

In-plant or in-community reductions of PM should be required instead of allowing trading in PM credits, and a very large (e.g., 20-to-1) offset rate could be employed for out-of-community offsets to ensure reductions stay local.

Permitting

Currently, AD staff is looking at reforming your permit program to take into account cumulative impact of emissions sources, rather than looking at each new permit as taking place on a clean slate.

We need to see other reforms in the permitting system at the Air District—for example:

- To close loopholes—for example, the piecemealing of larger projects into small components to remain under legal and regulatory thresholds and minimize the appearance of project impacts.**
- To change calculation methodologies that have resulted in over-permitting facilities (e.g., the 6th refinery problem).**

Cost-Benefit Analyses

Air District cost-benefit analyses need to take into account a broader portfolio of monetized health damages beyond the limited subset currently employed.

AD staff is pursuing updating the PM health values used in these analyses, which will make the comparison between costs to a facility and costs to public health less imbalanced and more accurate. We support this critical work, which the state should have moved on many years ago.

This does not replace the need to include the many health benefits/averted health costs that a regulation could achieve when engaging in socioeconomic analyses.

Authority & Measurement

There are so many places where the Air District doesn't have authority and can't ensure emissions will come down as needed to protect—so where you do have authority, you need to take maximal action.

PM counters that at least provide ballpark figures would be superior to subjective opacity determinations.

Conclusions

PM pollution is every bit as injurious and deadly as it was when you met in October and December, but now we are all moving forward trying to address this difficult challenge in a more trying environment.

In this environment, it is even more important than ever to identify and prioritize major sources of PM with a rapid timeline of control.

The most important thing we have learned from this crisis can be summarized in the old Boy Scout motto: BE PREPARED. The Air District can help prepare us for the next health crisis by greatly reducing PM emissions and improving our baseline health and safety.

Thanks!

jed@350bayarea.org



COVID WHILE BLACK



Bay O Vista
Rodeo, CA
10/15/19



SHITTEESHIIII
SHITTEESHIIII 🤔🤔

Low Income
Bay O Vista
Housing Units
Rodeo, CA
10/15/19



RODEO, CA
10/15/19





SOUTH VALLEJO CARQUINEZ BRIDGE 10/27/19



SOUTH VALLEJO CARQUINEZ BRIDGE HWY 80 10/27/19



BAY AREA
AIR QUALITY
MANAGEMENT
DISTRICT

AGENDA: 5

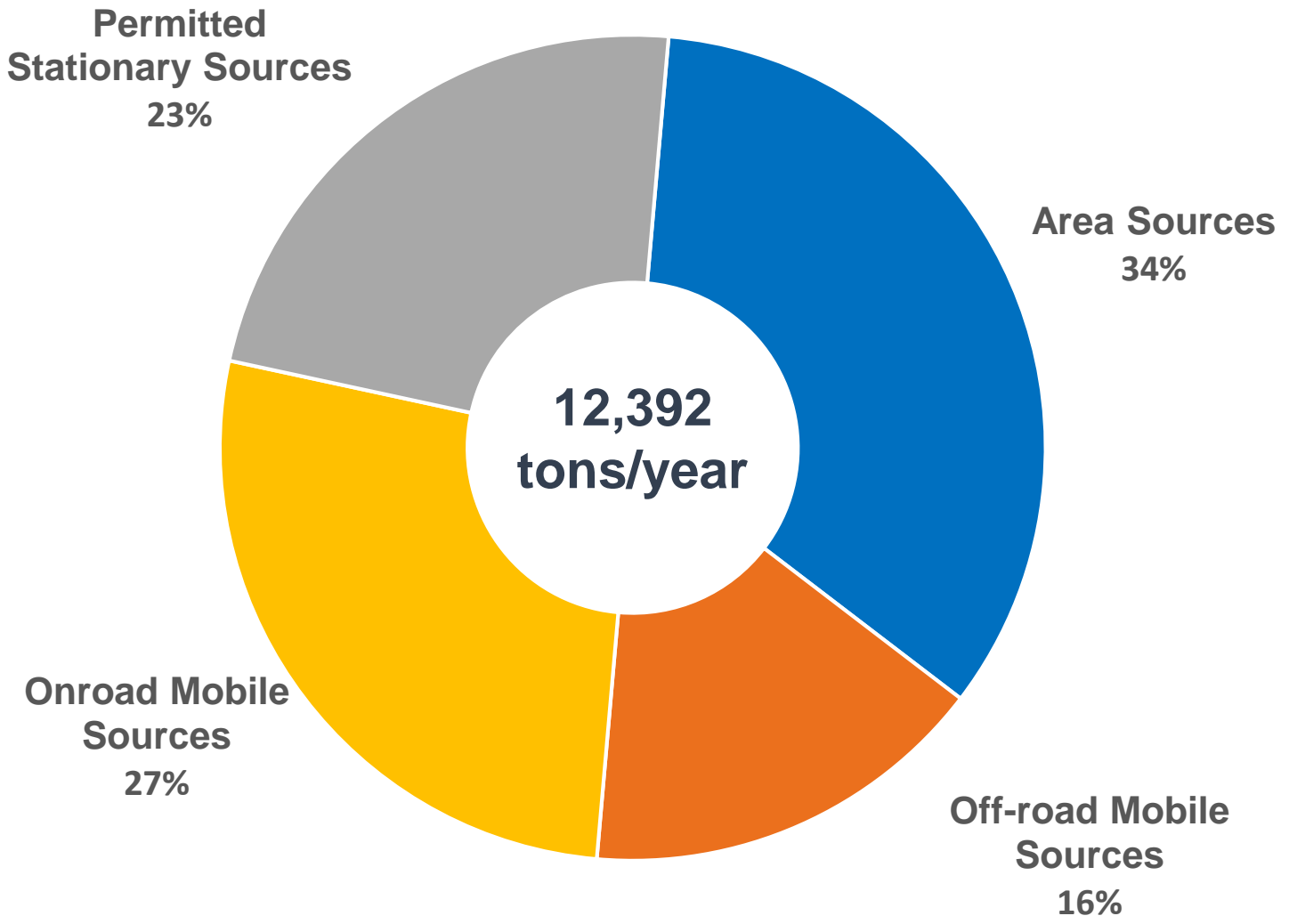
Update on Air District Particulate Matter (PM) Potential Policy Strategies

Advisory Council Meeting
May 12, 2020

Greg Nudd

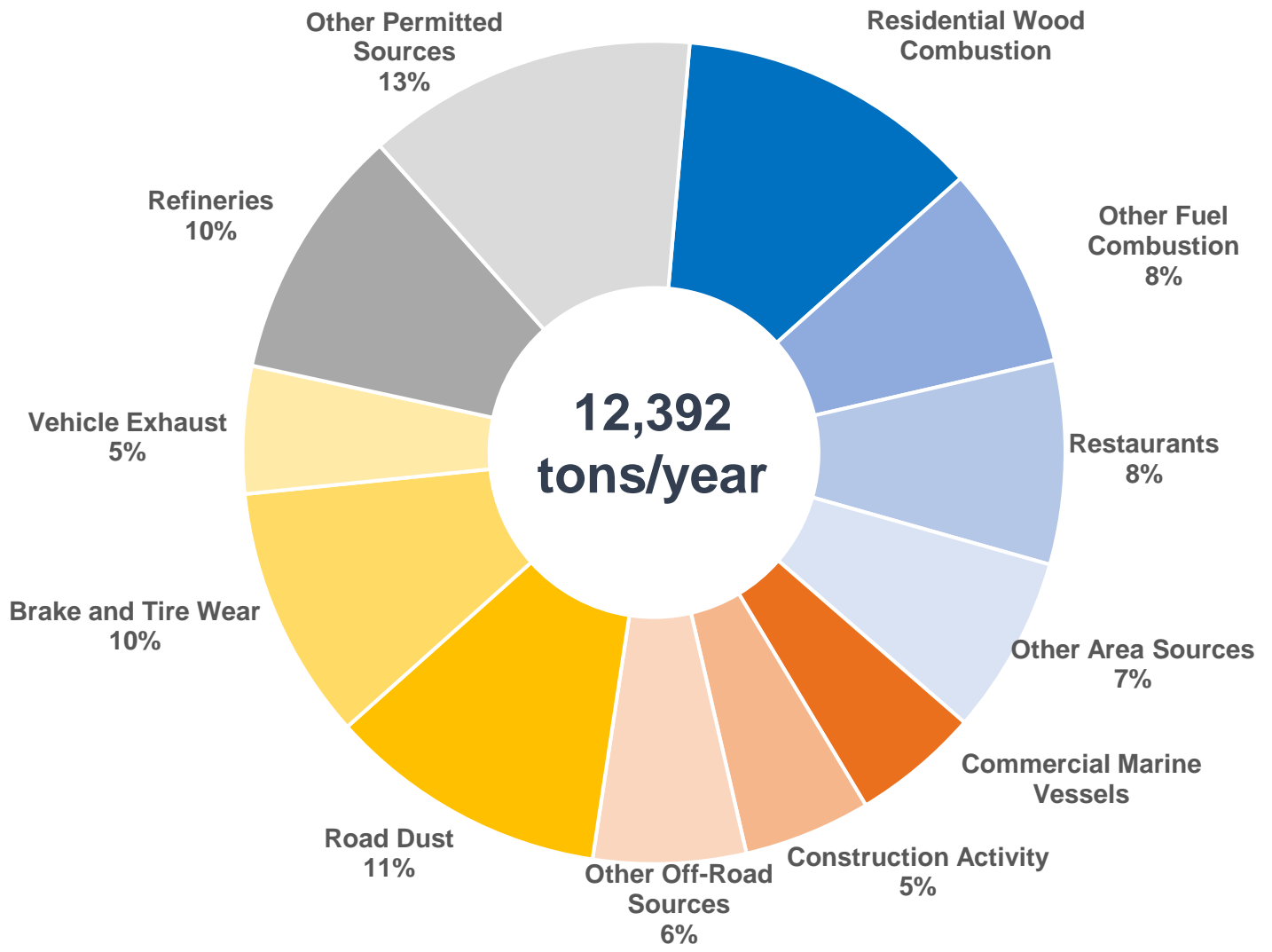
Deputy Air Pollution Control Officer

Major Sources of PM_{2.5} in the Bay Area



**2016 annual average,
directly emitted PM_{2.5}
emissions**

Major Sources of PM_{2.5} in the Bay Area

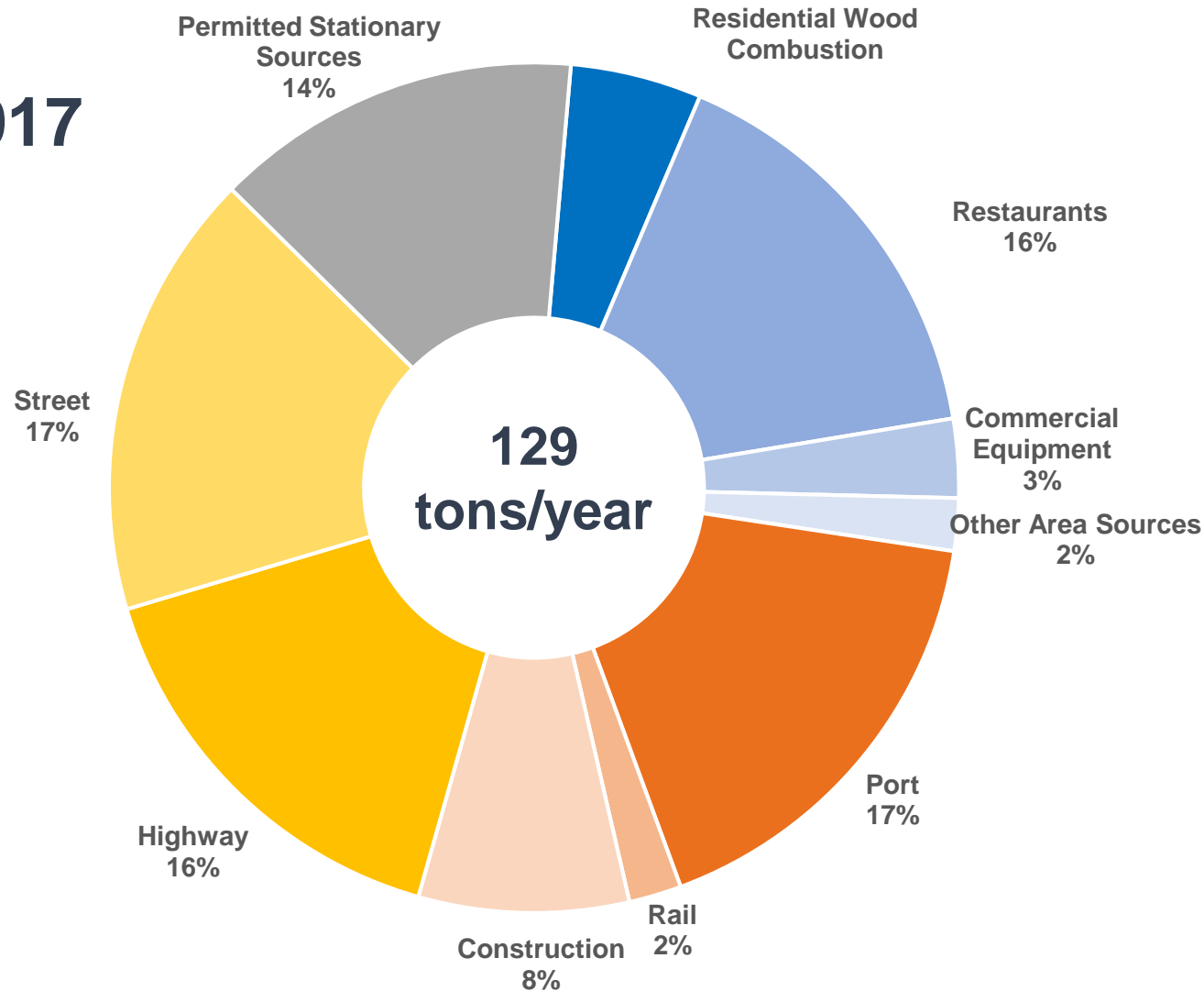


**2016 annual average,
directly emitted PM_{2.5}
emissions**

Major Sources of PM_{2.5} in West Oakland

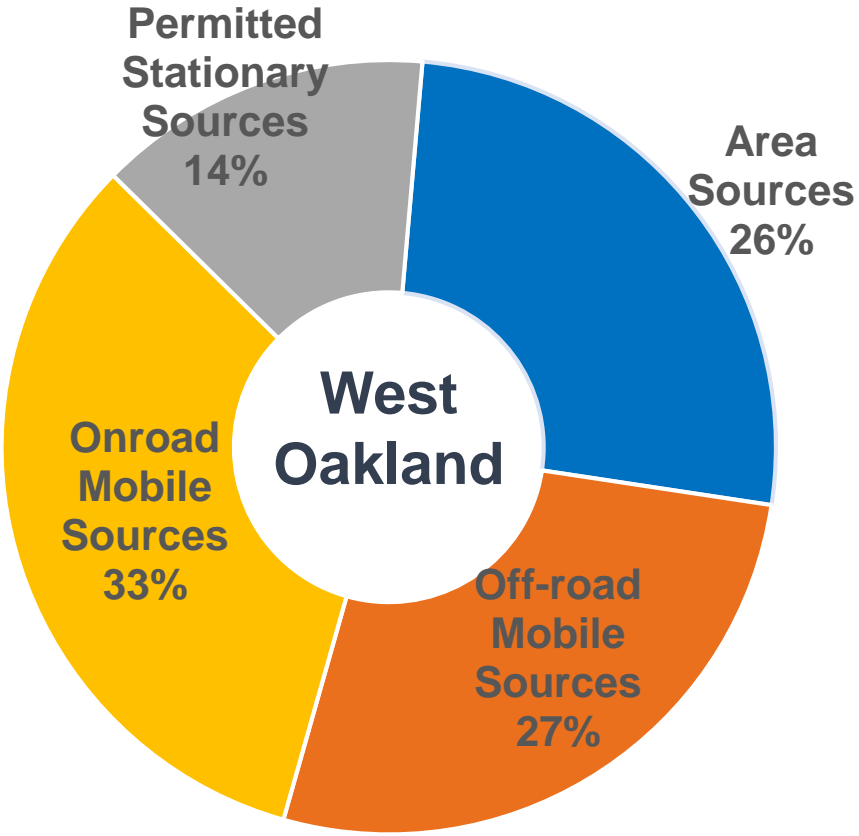


2017

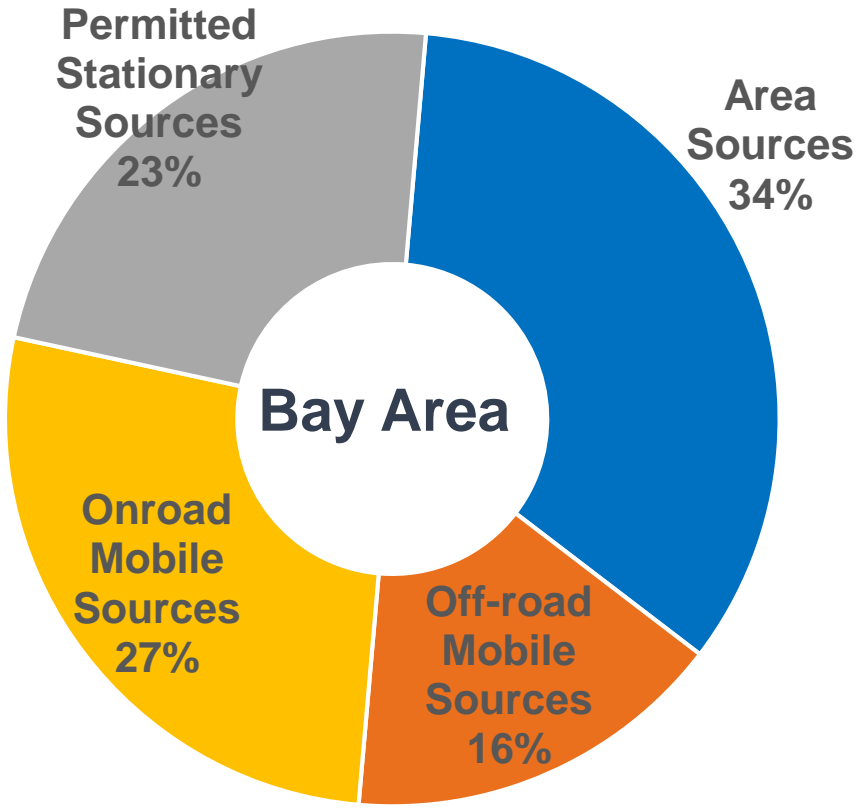


2017 annual average,
directly emitted PM_{2.5}
emissions

PM_{2.5} in West Oakland vs Bay Area



2017



2016

Current and Potential Actions



Mobile Sources

**Permitted
Stationary
Sources**

Area Sources

Magnet Sources

Current and Potential Actions



On Road Mobile Sources

**Regulatory Authority:
California Air
Resources Board
(CARB)**

- **Existing programs:**
 - Diesel Free by '33
 - Spare the Air
 - Incentives for trip reduction (shuttles, bicycles)
 - Vehicle Buy-backs
 - Commuter benefits rule
 - Air District Incentives Programs
- **Potential new programs:**
 - Encourage telework
 - Assist local programs to control road dust

Current and Potential Actions (cont.)



Off Road Mobile Sources

**Regulatory Authority:
CARB**

- **Existing Programs:**
 - Diesel Free by '33
 - Robust incentive programs for ships, trains, construction equipment
- **Potential New Programs:**
 - Push for stricter rules from CARB
 - Seek federal funding for electrification infrastructure

Current and Potential Actions (cont.)



Area Sources

**Regulatory Authority:
Air District**

- **Existing Programs:**
 - Restrictions on wood burning devices
 - Winter Spare the Air Program
 - Rule limiting charbroiler emissions
- **Potential New Programs:**
 - Require disabling of wood burning devices upon sale
 - Use regulatory authority to encourage electric space and water heating
 - Incentives for restaurant emission controls

Current and Potential Actions (cont.)



Permitted Stationary Sources

**Regulatory Authority:
Air District**

- **Existing Programs:**
 - Multiple current regulations to reduce PM from refineries, metal foundries, coke calcining, materials handling
 - New requirements under development to limit condensable PM from refineries and the cement kiln
 - Permitting rules cap PM and precursors region-wide
- **Potential New Programs:**
 - New rule to limit site-wide health risk from PM
 - Modify permitting regulations to address localized health risks

Current and Potential Actions (cont.)

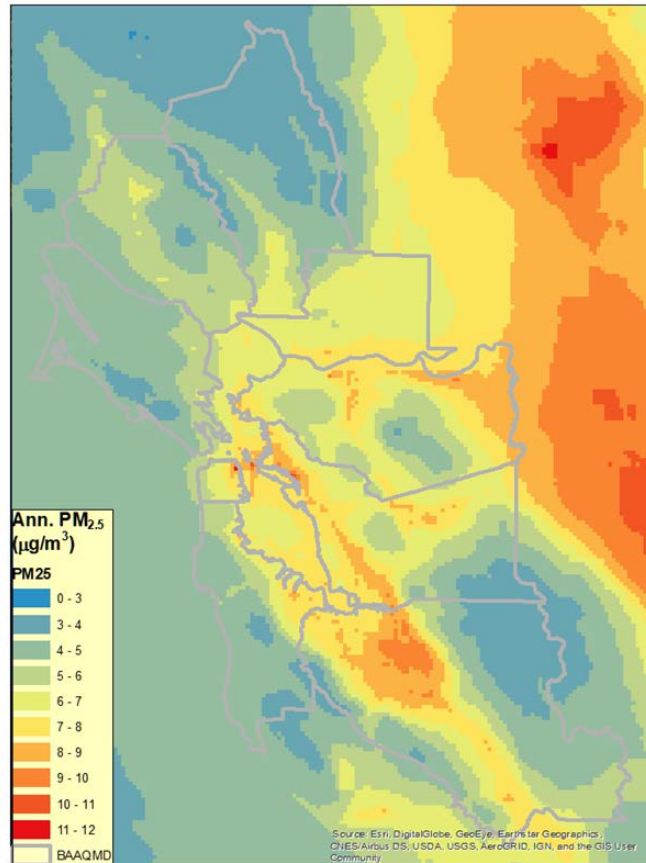


Magnet Sources

Regulatory Authority:
?

- **Magnet Source Rule(s)**
Businesses that attract mobile sources: Examples: US Post Office facilities, port warehouses, and distribution centers
Rule Development status: seeking changes to Air District authority at the state level

Gaps in Authority to Regulate PM



- Fine PM as Toxic Pollutant
- Establish Air Quality Standards for PM
- Magnet Sources of all forms of PM

Reducing Health Impacts of Fine PM



Air District Next Steps

- **Considerations of health impacts**
 - Community-level health exposure assessments
 - Health-benefit analyses
- **Establish “Goals” for PM reductions**
- **Additional Rule Development Efforts**



Questions?

PRESENTATION TO BAAQMD ADVISORY COMMITTEE

Proposed Guiding Principles for Consideration in Forwarding
Recommendations to the BAAQMD on PM2.5 Regulation

Frances Keeler, CCEEB
July 31, 2020



California Council for Environmental and Economic Balance

The California Council for Environmental and Economic Balance (CCEEB) is a nonpartisan, nonprofit coalition of labor, business, and public leaders that advances strategies for a healthy environment and sound economy. CCEEB represents many facilities that operate in the Bay Area Air Quality Management District.

Guiding Principles

Recommendations from the AC to the BAAQMD should:

- Be based on best peer-reviewed science
- Consider input/lessons learned from other agencies
- Consider PM_{2.5} speciation and source apportionment
- Address regional vs local impacts and control strategies
- Include an economic evaluation
- Prioritize strategies by greatest amount of near-term, cost-effective reductions

Scientifically Based Recommendations

Recommendations:

- Must be informed by the best, scientifically-based data possible
 - *Is more data needed and , if so, what is needed?*
- Should be based on peer-reviewed studies
- Should consider guidance developed by other agencies
- Data collection versus modeling
- Should demonstrate causal relationship before recommending controls
- Should be all inclusive

Coordination Between Agencies

- AC should consult other agencies on health standards
 - CARB – sets SAAQS
 - OEHHA
 - CA Air Districts
- AC Should direct Staff to work with other agencies
- AC should consider measures agencies are implementing to reduce PM and how it might advance the goals of the BAAQMD
 - CARB is adopting many strategies for mobile sources that will reduce $PM_{2.5}$
 - BAAQMD has regulations in the plan and in process to further reduce $PM_{2.5}$
 - State is developing strategies to address wildfires

PM Speciation

- **Advisory Council must examine speciation**
- **There are many contributors to PM2.5**
 - *Mobile sources*
 - *Commercial sources (restaurants)*
 - *Residential sources (wood burning fireplaces, fire pits, BBQs)*
 - *Material handling*
 - *Industrial combustion sources*
 - *Secondary formation sources*
 - *Naturally occurring sources*
 - *Wildfires*
- **Speciation/source apportionment are key to determining the most effective means of reduction**
 - *Not about exoneration, but about effectiveness*

Regional vs Local Controls

- **PM_{2.5} levels vary at the localized level**
 - *Different sources contribute to PM_{2.5} levels in different communities*
- **Are regional reductions more effective than localized reductions?**
- **What is the goal and how do we best achieve it?**
- **Have the COVID response measures changed impacts on either the regional or local level and is any of the change permanent?**

Economic Impacts

- Need to focus limited resources where they will be most effective
- AC should review research that includes economic analysis of potential PM control strategies and identify/recommend proven strategies that can be implemented expeditiously and economically

Prioritize Recommended Measures

- Identify the goal and recommend:
 - *Measures with greatest ground-level concentration reductions*
 - *Measure with greatest impact*
 - *Measures available near-term versus future reductions*
 - *Most cost-effective measures*
 - *Measures that reduce the most impactful portion of PM_{2.5}*

Factors Beyond the Scope of the Advisory Council

- District Authority
 - *State and Federal government establish standards/regulate mobile sources*
- CEQA analysis of control options
- Resources
- Cost-effectiveness threshold

BAAQMD Action on Advisory Council Recommendations

- **Action informed by best, scientifically-based data possible**
 - *Will help determine what to regulate first and where/how to get the most effective reductions*
- **Consider input/peer review/actions from other agencies**
 - *What vetted methods are other agencies doing to reduce PM_{2.5} emissions*
 - *How might those regulations benefit the Bay Area?*
- **Regional vs Local Control**
 - *Where should BAAQMD focus its attention first?*
- **Consider PM_{2.5} speciation/source apportionment**
 - *Important to determining the most effective approach*
- **Include economic evaluation**
 - *How to obtain the greatest cost-effective reductions?*



Assessing the Health Effects of Particulate Matter

**Julie E. Goodman, Ph.D., DABT, FACE, ATS
Gradient**

Bay Area Air Quality Management District

Advisory Council Meeting
July 31, 2020

Julie E. Goodman, PhD, DABT, FACE, ATS

- SB, Environmental Engineering, MIT, 1996
- ScM, Epidemiology, Johns Hopkins, 2000
- PhD, Toxicology, Johns Hopkins, 2002
- Cancer Prevention Fellow, National Cancer Institute, 2002-2004
- Principal, Gradient, 2004-Present
- Board of Health, Canton, MA, 2008-Present
- Adjunct Faculty, Harvard School of Public Health, 2009-2017
- Diplomate, American Board of Toxicology
- Fellow, American College of Epidemiology
- Fellow, Academy of Toxicological Sciences



Health Sciences

Epidemiology – The study of the distribution and determinants of health effects



Toxicology – The study of potential adverse health effects of substances on living organisms



PM Associations vs. Causation

- PM is associated with morbidity and mortality in many traditional epidemiology studies
- Associations, particularly at low concentrations, are small in magnitude
- Association does not always mean causation
- Most likely explanation
 - Bias (*e.g.*, exposure measurement error)
 - Confounding
 - Chance
 - Inappropriate statistical model

The NEW ENGLAND JOURNAL of MEDICINE

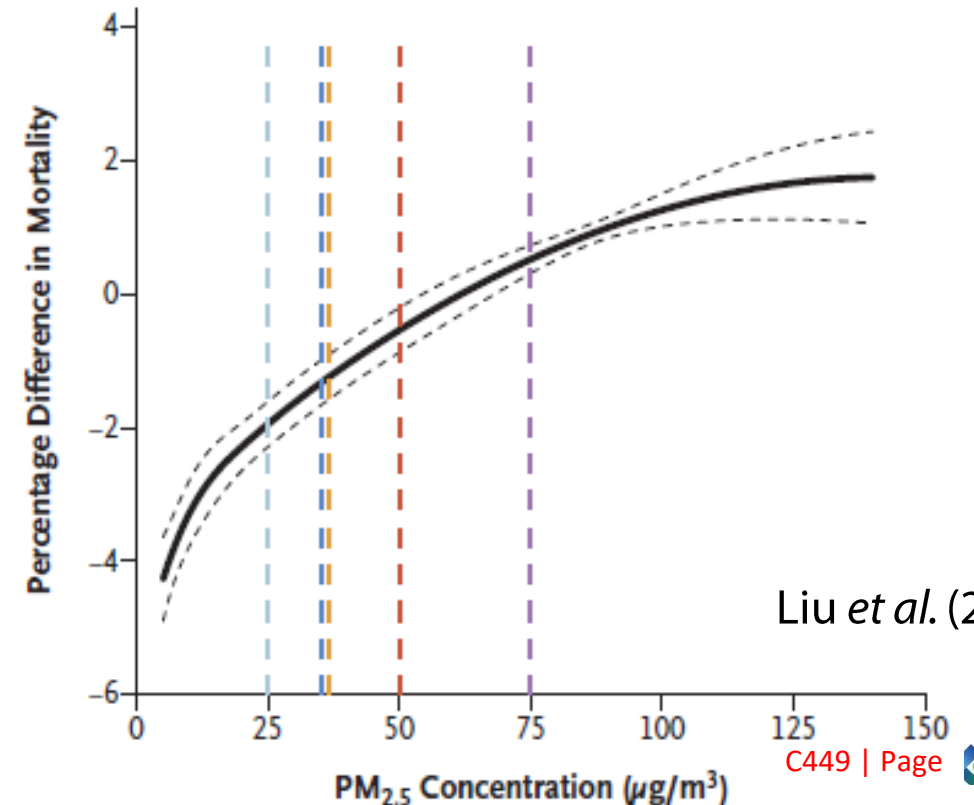
ESTABLISHED IN 1812

AUGUST 22, 2019

VOL. 381 NO. 8

Ambient Particulate Air Pollution and Daily Mortality in 652 Cities

WHO AQG | US NAAQS | WHO IT-3 | WHO IT-2 | WHO IT-1;
China AQS



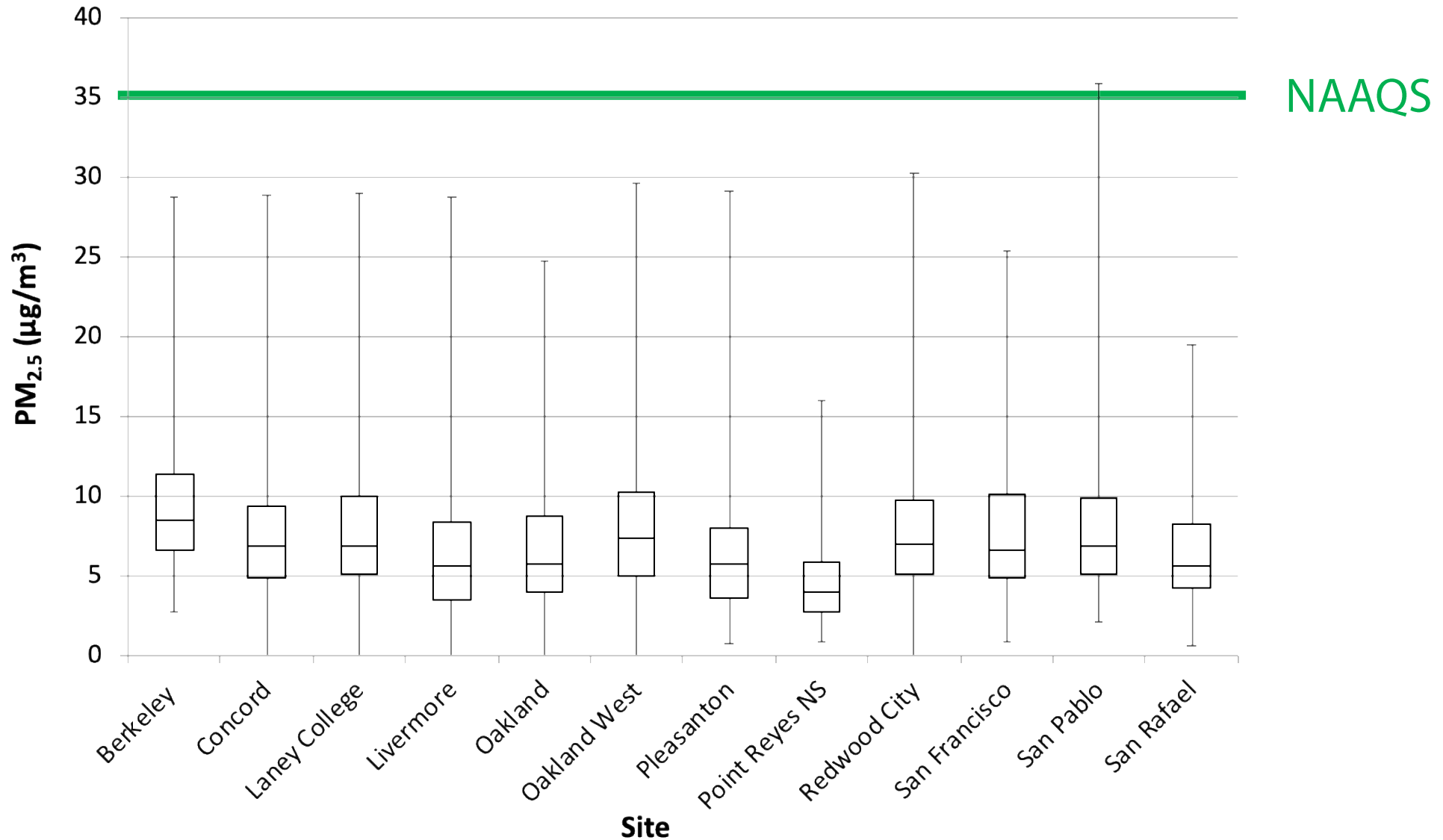
Liu *et al.* (2019)

H. Christopher Frey June Air Quality Presentation, June 2020

- Need to consider population density, multiple pollutants, other factors
- Issues with the validity of using satellite retrieval without ground-based validation
- Larger cities have higher levels of air pollution and an increased opportunity for the spread of disease because there are many more people

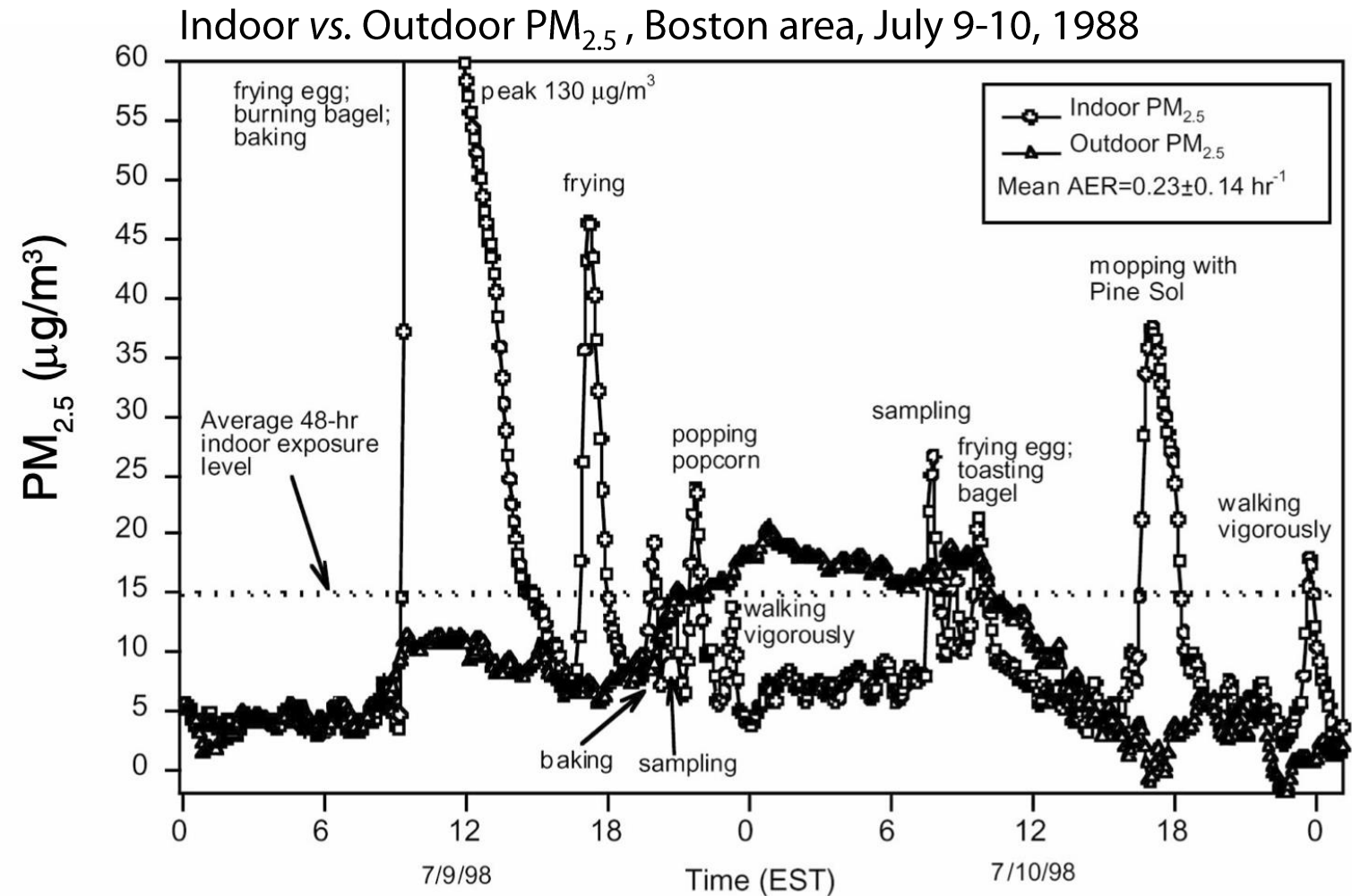
There are similar issues with PM epidemiology in general

Daily Average PM_{2.5} Concentrations in the Bay Area, 2019



Exposure Measurement Error – Ambient Air Monitors

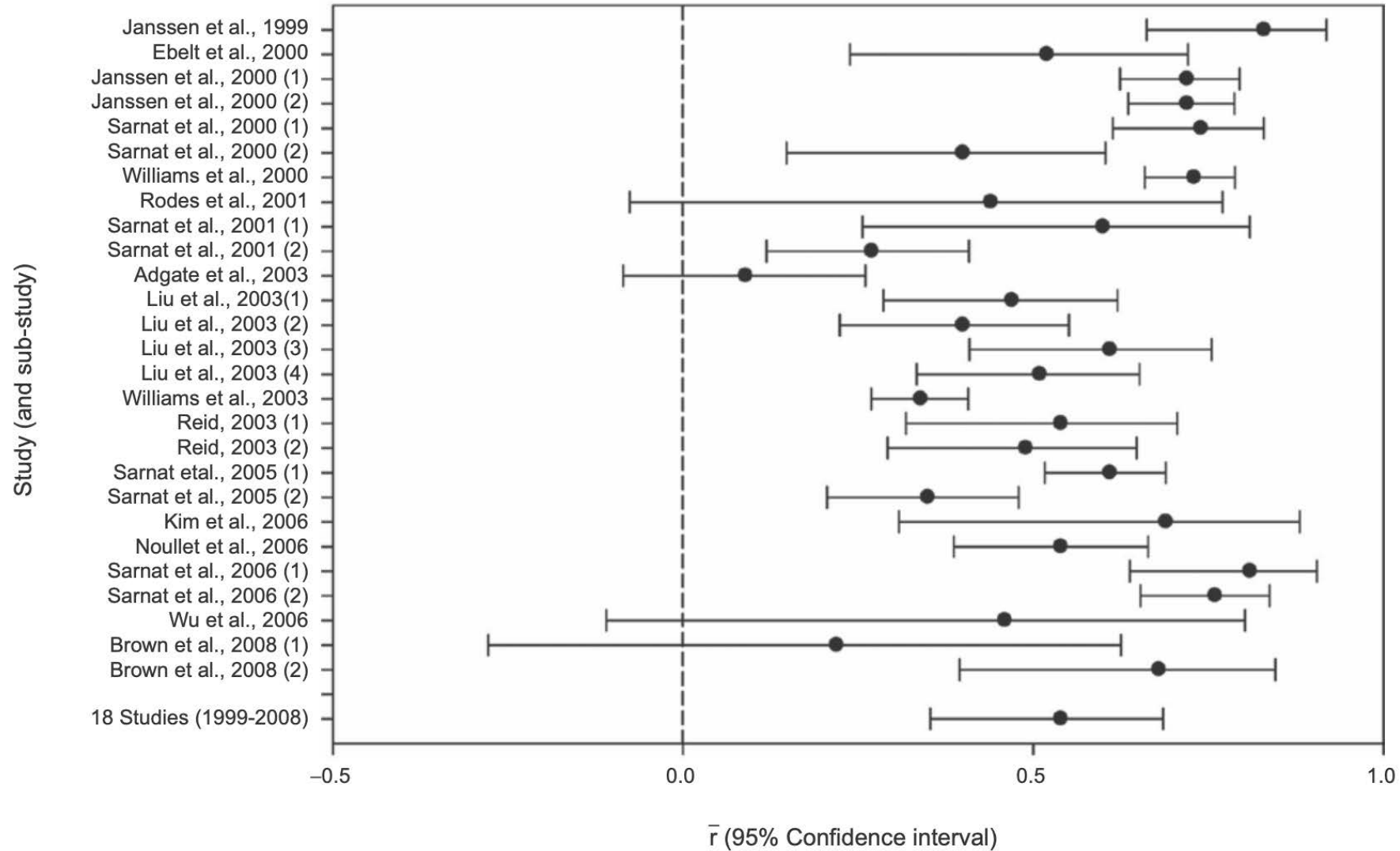
- Most studies use ambient air monitors
- People often spend a lot of time away from home
- People spend most time indoors
- Average PM exposures can be higher indoors



Long et al. (2000)

Harvard School of Public Health

Exposure Measurement Error – Personal vs. Ambient PM_{2.5} Associations Vary



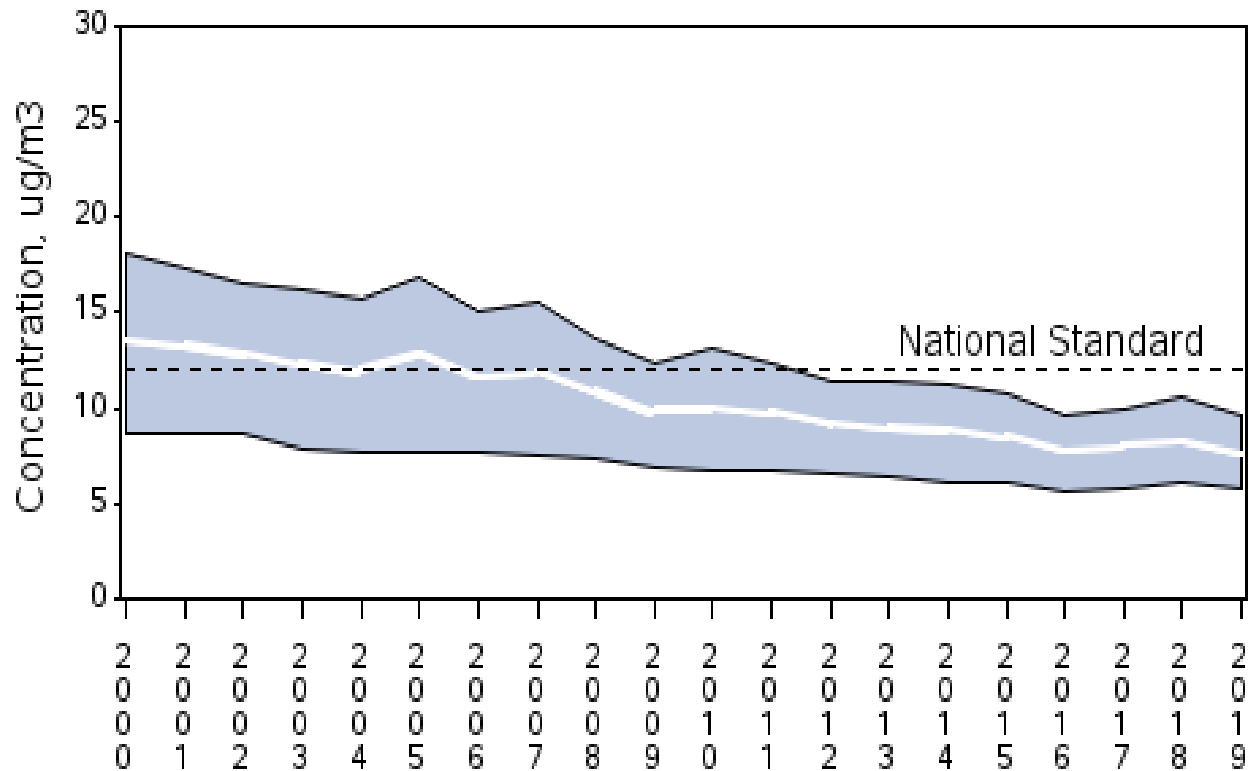
Avery *et al.* (2011)

Exposure Measurement Error – Many Studies Evaluate the Wrong Exposure Window and Overestimate Associations

PM_{2.5} Air Quality, 2000 - 2019

(Seasonally-Weighted Annual Average)

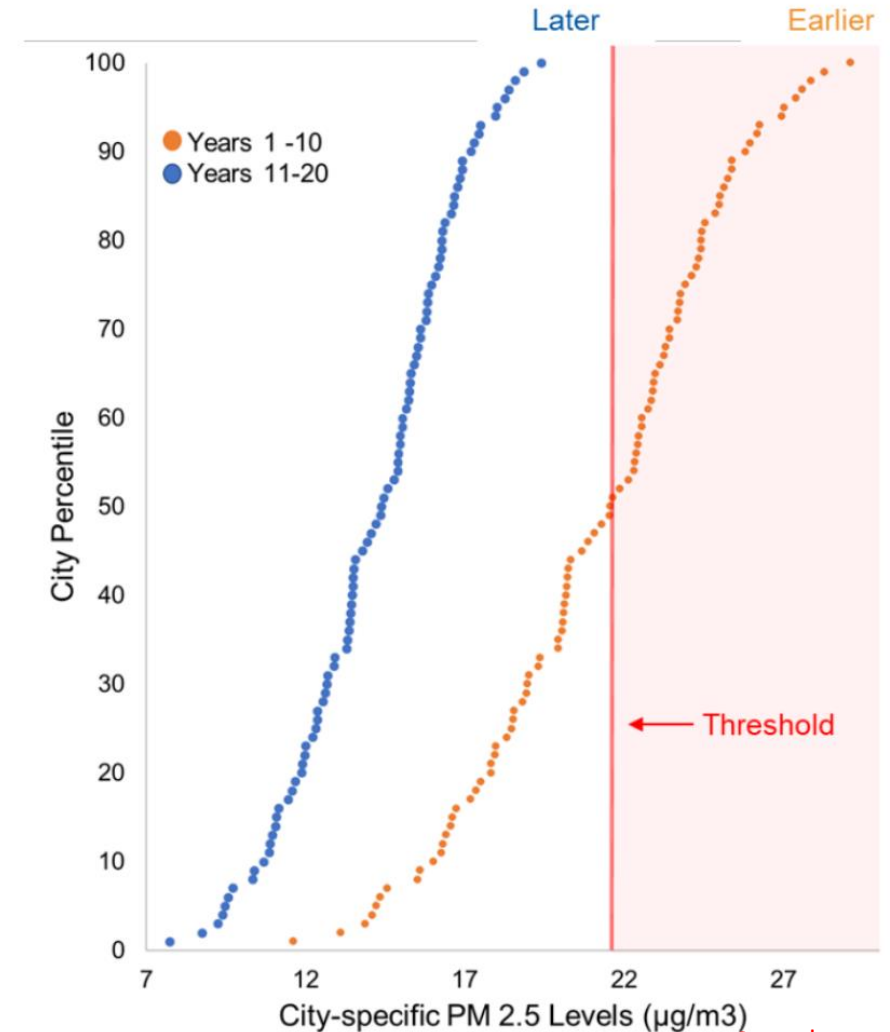
National Trend based on 406 Sites



2000 to 2019 : 43% decrease in National Average

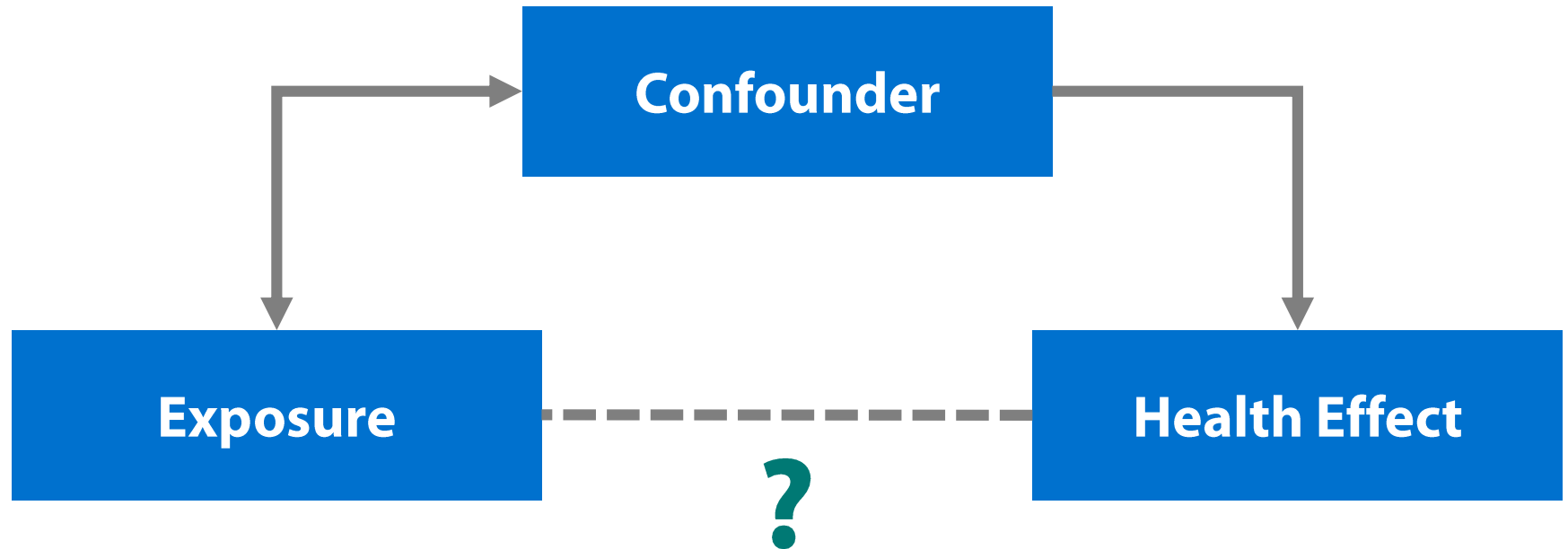
US EPA, 2020

Figure 1. PM_{2.5} Distributions in Illustrative Example



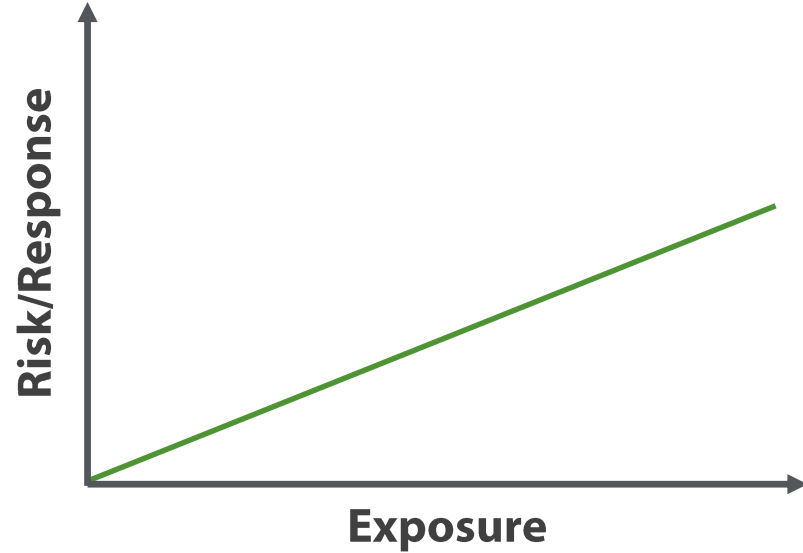
Confounding

- Other exposure window
- Atmospheric conditions
- Other copollutants, allergens
- Socioeconomic status (SES)
- Lifestyle factors (e.g., smoking)
- Access to health care
- Genetics

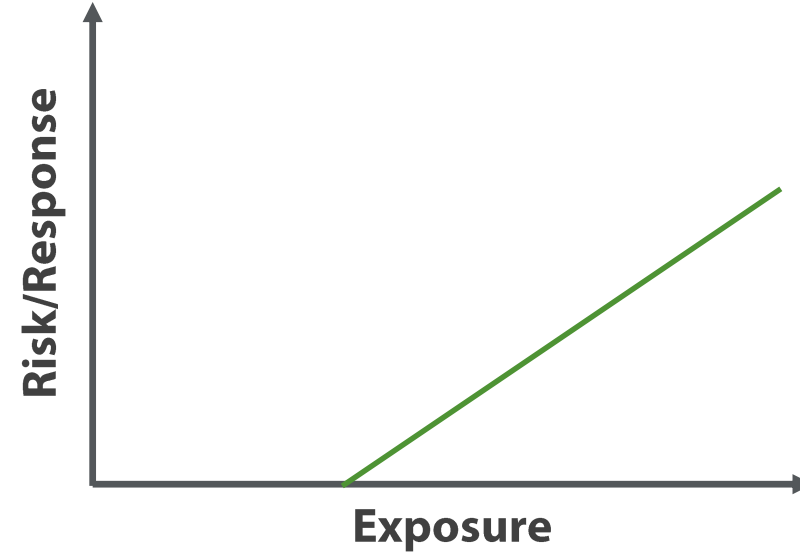


Model Choice and Measurement Error Linearizes Exposure-response Curve

No Threshold



Threshold



REVIEW ARTICLE

Measurement error in environmental epidemiology and the shape of exposure-response curves

Lorenz R. Rhomberg, Juhi K. Chandalia, Christopher M. Long, and Julie E. Goodman

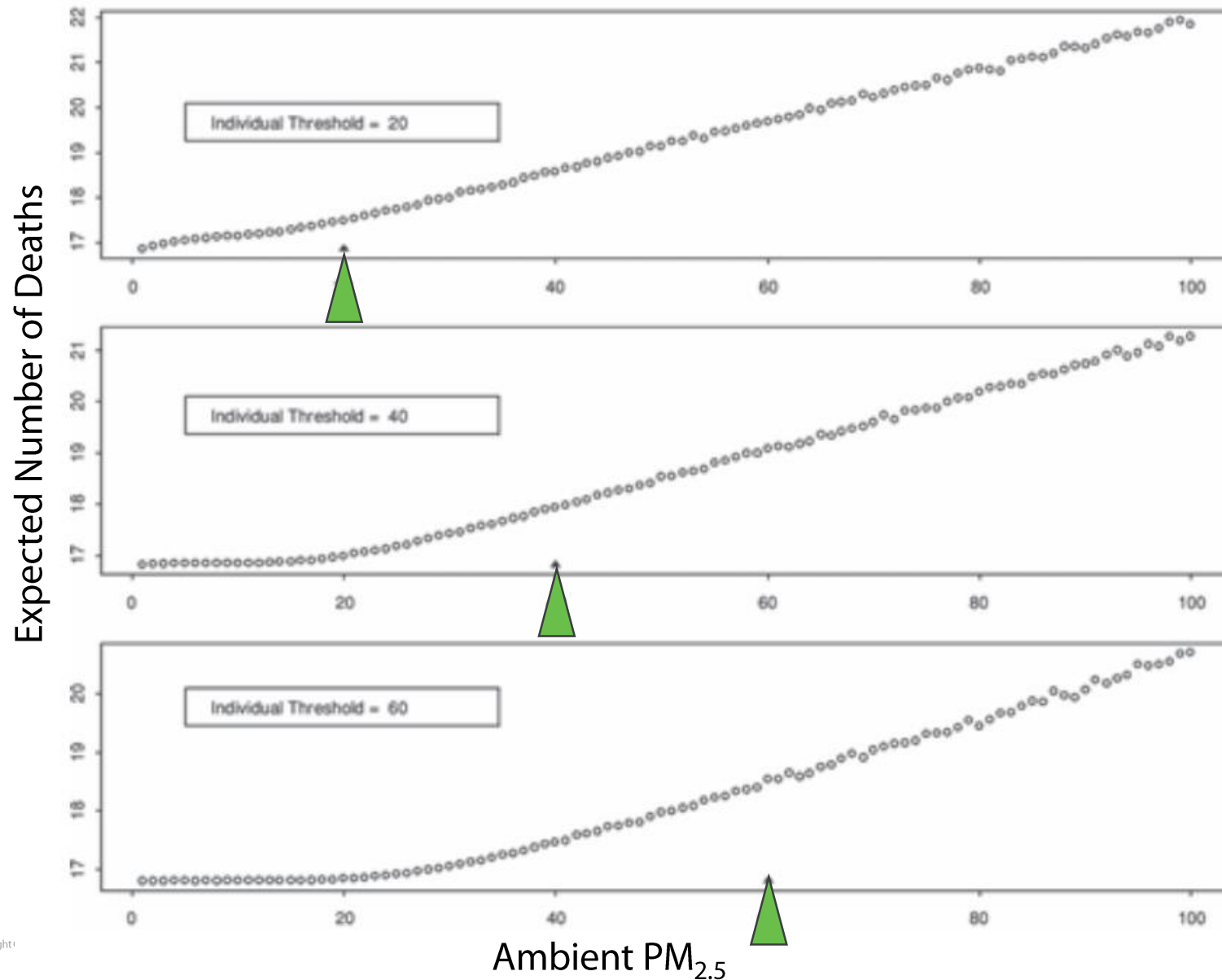
Gradient, Cambridge, Massachusetts, USA

Abstract

Both classical and Berkson exposure measurement errors as encountered in environmental epidemiology data can result in biases in fitted exposure-response relationships that are large enough to affect the interpretation and use of the apparent exposure-response shapes in risk assessment applications. A variety of sources of potential measurement error exist in the process of estimating individual exposures to environmental contaminants, and the authors review the evaluation in the literature of the magnitudes and patterns of exposure measurement errors that prevail in actual practice. It is well known among statisticians that random errors in the values of independent variables (such as exposure in exposure-response curves) may tend to bias regression results. For increasing curves, this effect tends to flatten and apparently linearize what is in truth a steeper and perhaps more curvilinear or even threshold-bearing relationship. The degree of bias is tied to the magnitude of the measurement error in the independent variables. It has been shown that the degree of bias known to apply to actual studies is sufficient to produce a false linear result, and that although nonparametric smoothing and other error-mitigating techniques may assist in identifying a threshold, they do not guarantee detection of a threshold. The consequences of this could be great, as it could lead to a misallocation of resources towards regulations that do not offer any benefit to public health.

Keywords: Epidemiology, exposure, exposure-response, measurement error, risk assessment

Exposure Misclassification Masks or Biases Thresholds



- True exposure was modeled.
- Corresponding risks calculated for simulated population using error based on observed exposure measurement error.

▲ "True" threshold

Brauer *et al.* (2002)
University of British Columbia

Causal Methods Example – Burns *et al.* (2017)

Health Effects Institute Review of 42 Studies of 38 Interventions

Interventions

- Industrial
- Residential
- Vehicular
- Multiple

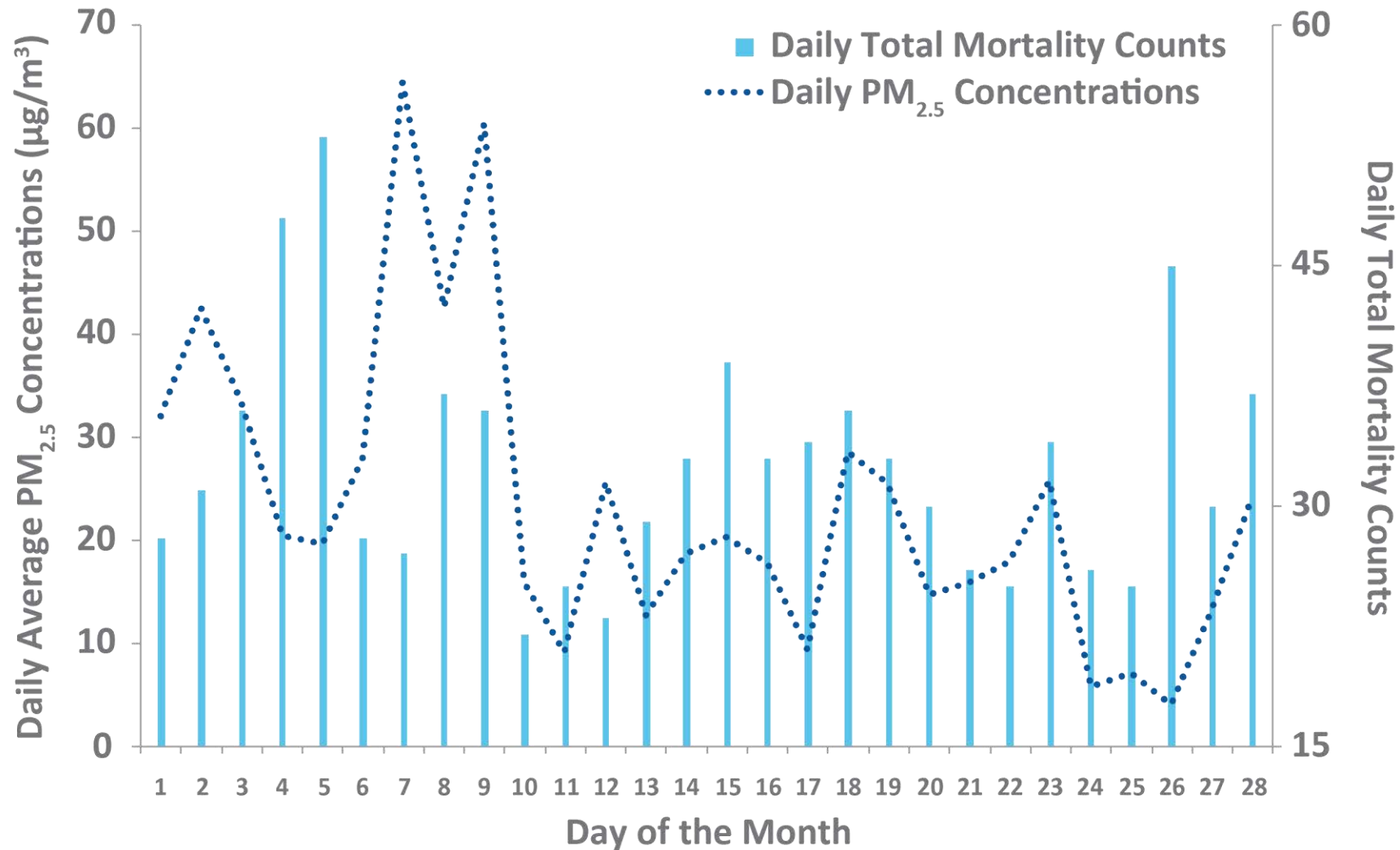
Comparison: *No restrictions*

Primary Outcomes

- All cause mortality
- Cardiovascular Mortality
- Respiratory Mortality
- PM₁₀
- PM_{2.5}
- Coarse PM
- Soot
- Black carbon (BC)
- Black smoke (BS)
- Elemental carbon (EC)

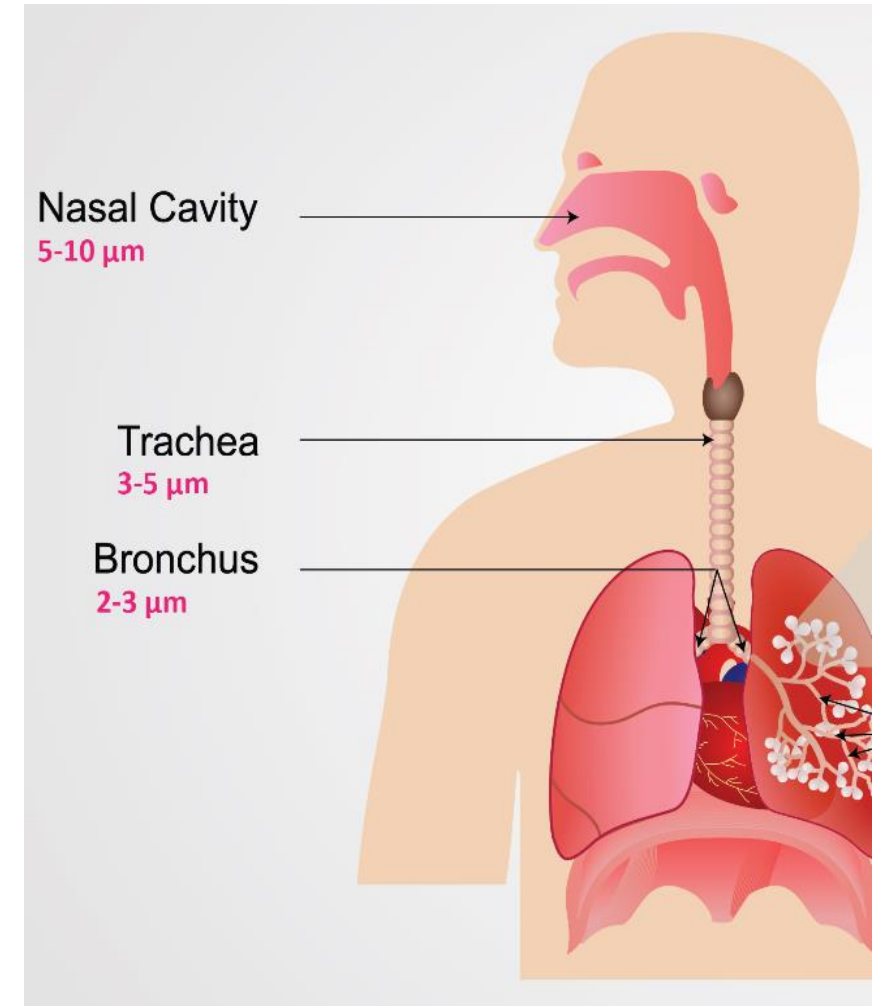
Results: "Evidence for effectiveness was mixed. Most included studies observed either no significant association or an association favoring the intervention, with little evidence that the assessed interventions might be harmful."

Example: PM_{2.5} and Mortality in Greater Boston, 2002, after Quebec Forest Fires



Toxicity Studies – There is a threshold below which people can be exposed to PM and not experience health impacts

- If exposures are sufficiently low, PM will not cause adverse health effects because it won't overwhelm the body's natural defenses.
- This is supported by experimental studies in humans and animals.
- CARB relies on this principle for all other non-carcinogenic agents.
- There is no justification for assuming one particle will impact health.



The Peer-review Process Is Not Perfect- Long-term PM and Mortality Example

Sources of Bias and Uncertainty		Crouse et al. (2012)	Crouse et al. (2015)	Villeneuve et al. (2015)	Chen et al. (2016)	Pinault et al. (2016)	Wong et al. (2015)	Beelen et al. (2014)	Cesaroni et al. (2013)	Lepeule et al. (2012)	Hart et al. (2015)	Shi et al. (2016)	Thurston et al. (2016)	Di et al. (2017a)
PM _{2.5} Exposure Assessment	Central site monitoring (low spatial resolution)									X				
	No validation for PM _{2.5} data						X						X	
	Temporal variation not accounted for	X	X	X	X			X	X					
	Residential mobility not accounted for	X		X		X	X	X		X		X		
	No evaluation on multiple exposure windows	X	X	X	X	X	X	X	X		X	X	X	X
	Personal activities not accounted for (e.g., time spent indoors)	X	X	X	X	X	X	X	X	X	X	X	X	X
	Mismatch of PM _{2.5} exposure window and mortality	X	X	X	X		X	X	X					X
Individual Covariates	No adjustment of individual covariates													
	Information bias (e.g., self-reported covariates)	X	X	X		X	X	X		X	X	X	X	
	Temporal variation not accounted for	X	X	X	X	X	X	X	X	X			X	
	Unmeasured confounding (e.g., pre-existing conditions)	X	X	X	X	X	X	X	X	X	X	X	X	X
Ecological Covariates	No adjustment of ecological covariates													
	Temporal variation not accounted for	X		X	X	X	X	X	X	X	X	X	X	
	Residential mobility not accounted for	X		X		X	X	X				X		
	Unmeasured confounding (e.g., access to health care, violence)	X	X	X	X	X	X	X	X	X	X	X	X	X
Evaluation of Copollutants	No adjustment of copollutants													
	Central site monitoring (low spatial resolution)												X	
	No validation for copollutants data												X	
	Temporal variation not accounted for	X	X	X	X	X	X	X	X	X	X	X	X	
	Residential mobility not accounted for							X				X		
	Personal activities not accounted for (e.g., time spent indoors)		X					X	X			X	X	
	Collinearity/nonlinear relationship with PM _{2.5} not addressed/accounted for												X	
	Mismatch of copollutants window and mortality		X					X	X				X	X
Statistical Analyses	Model assumptions not tested/relaxed		X	X		X	X	X	X		X	X	X	X
	C-R curves sensitive to <i>df</i> (natural splines)	X	X	X	X	NR	X	X	X				X	
	Nonlinearity not assessed statistically			X		X					X	X	X	X
	Threshold not assessed	X	X		X		X		X	X	X	X	X	X

Conclusions – PM Threshold Is Likely Higher than Ambient Concentrations

- High concentrations of PM, and every other substance, can impact morbidity.
- There are clearly statistical associations between PM and morbidity and mortality in many epidemiology studies, even at lower, ambient concentrations.
- Evidence does not indicate associations are causal at ambient concentrations.
- There is a threshold below which people can be exposed to PM and not experience health impacts.





BAY AREA
AIR QUALITY
MANAGEMENT
DISTRICT

AGENDA: 5

Bay Area Particulate Matter (PM) Modeling- Based Assessments and Next Steps

Advisory Council Meeting
July 31, 2020

Phil Martien, PhD
Director of Assessment, Inventory, & Modeling Division

Overview



- PM modeling for the West Oakland Community Action Plan
 - Review community-scale assessment
- PM modeling of large industrial sources
 - Chevron Richmond Refinery
- Next Steps

Recent PM Assessments

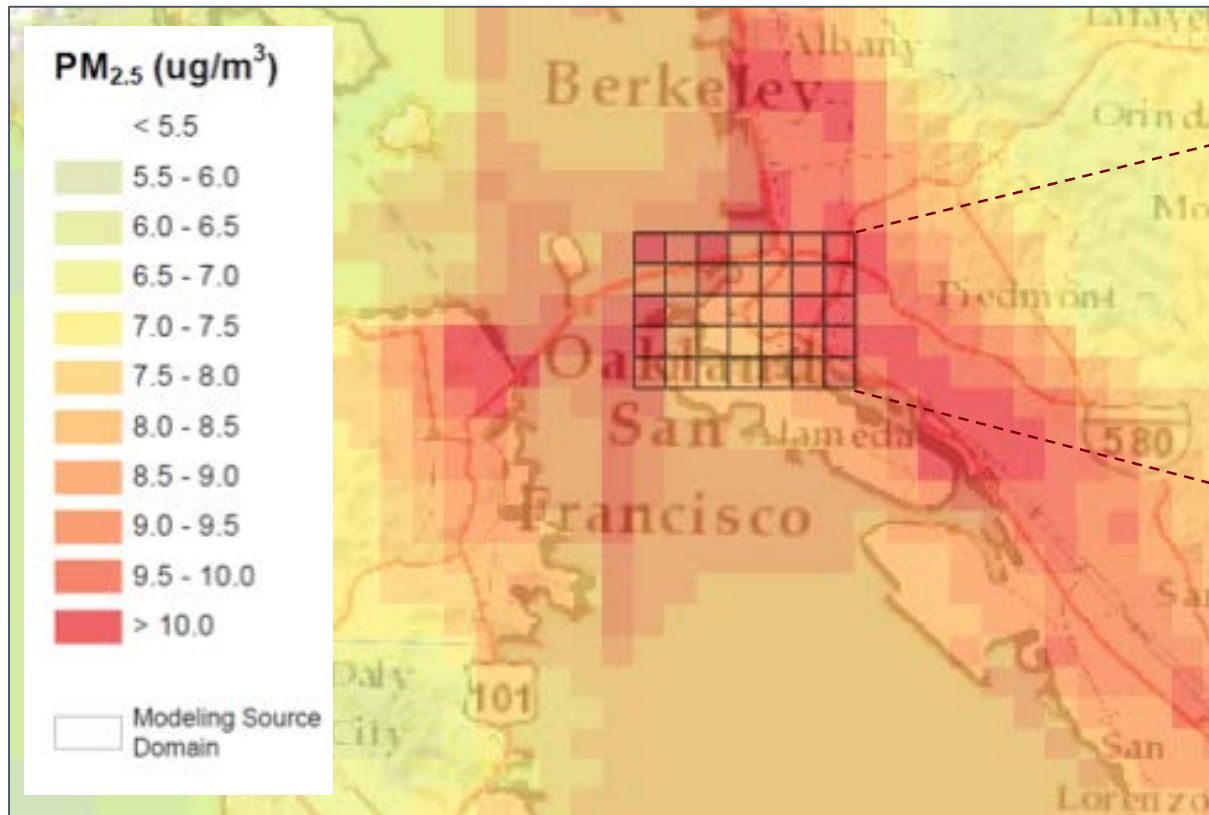


- Identify source-contributions to impacts
 - What is responsible?
- Assess equity of impacts to inform decision-making
 - Support agency goal of reducing air pollution inequities
- Work toward highlighting health risks from fine PM (PM_{2.5}) exposures below federal standard
 - Develop a risk framework consistent with “no identified safe level of PM_{2.5}”

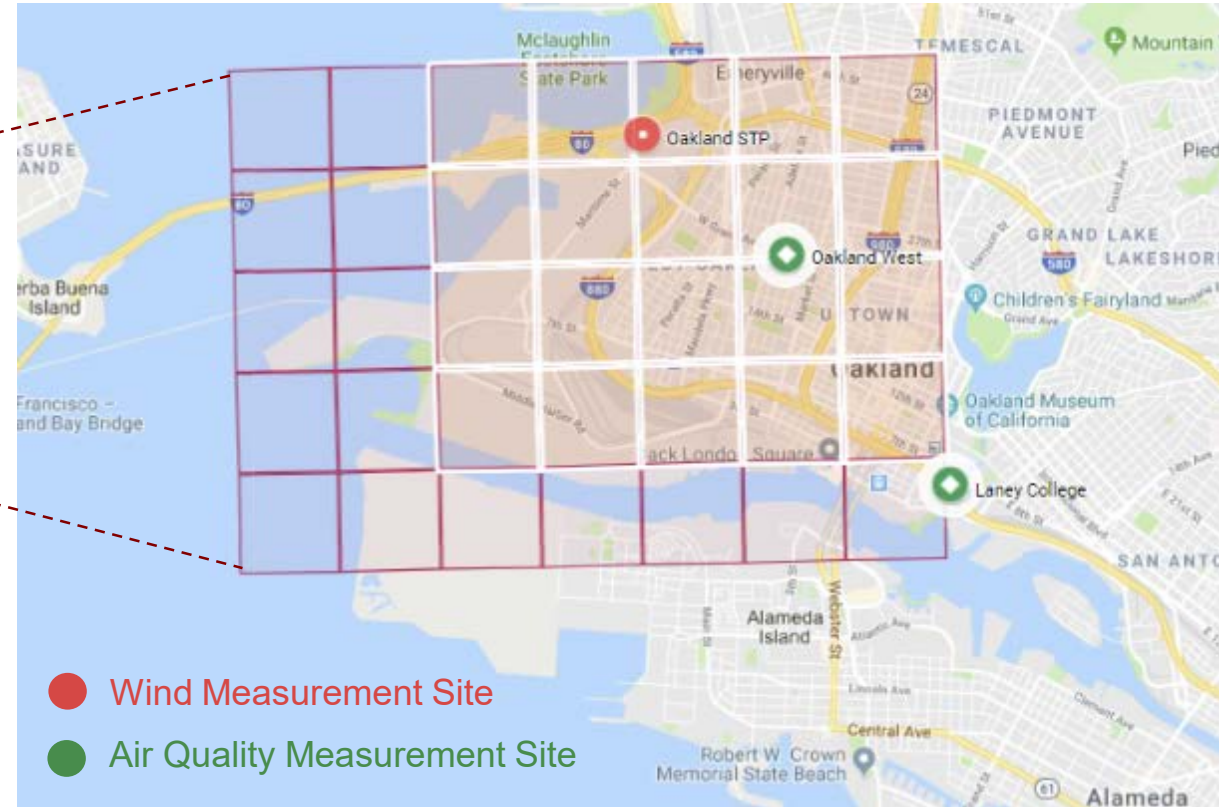


West Oakland Community Action Plan

Regional-Scale and Community-Scale Modeling (2017)



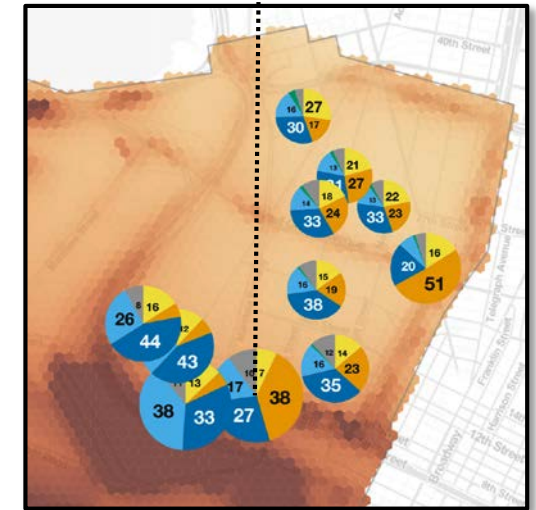
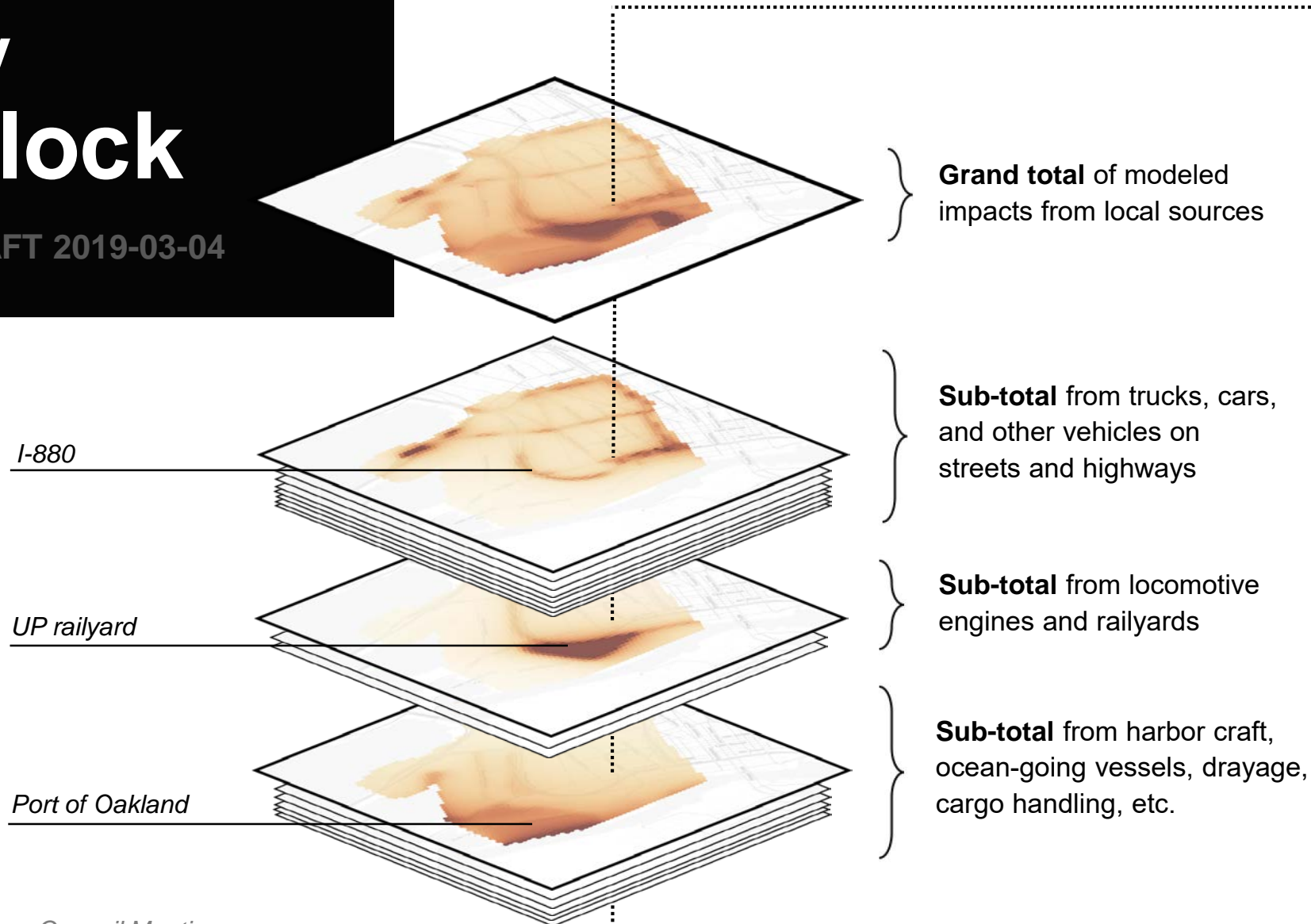
Regional-scale modeling: covers the Bay Area



Local-scale modeling: covers West Oakland, including impacts in receptor area (white) from sources in source area (red)

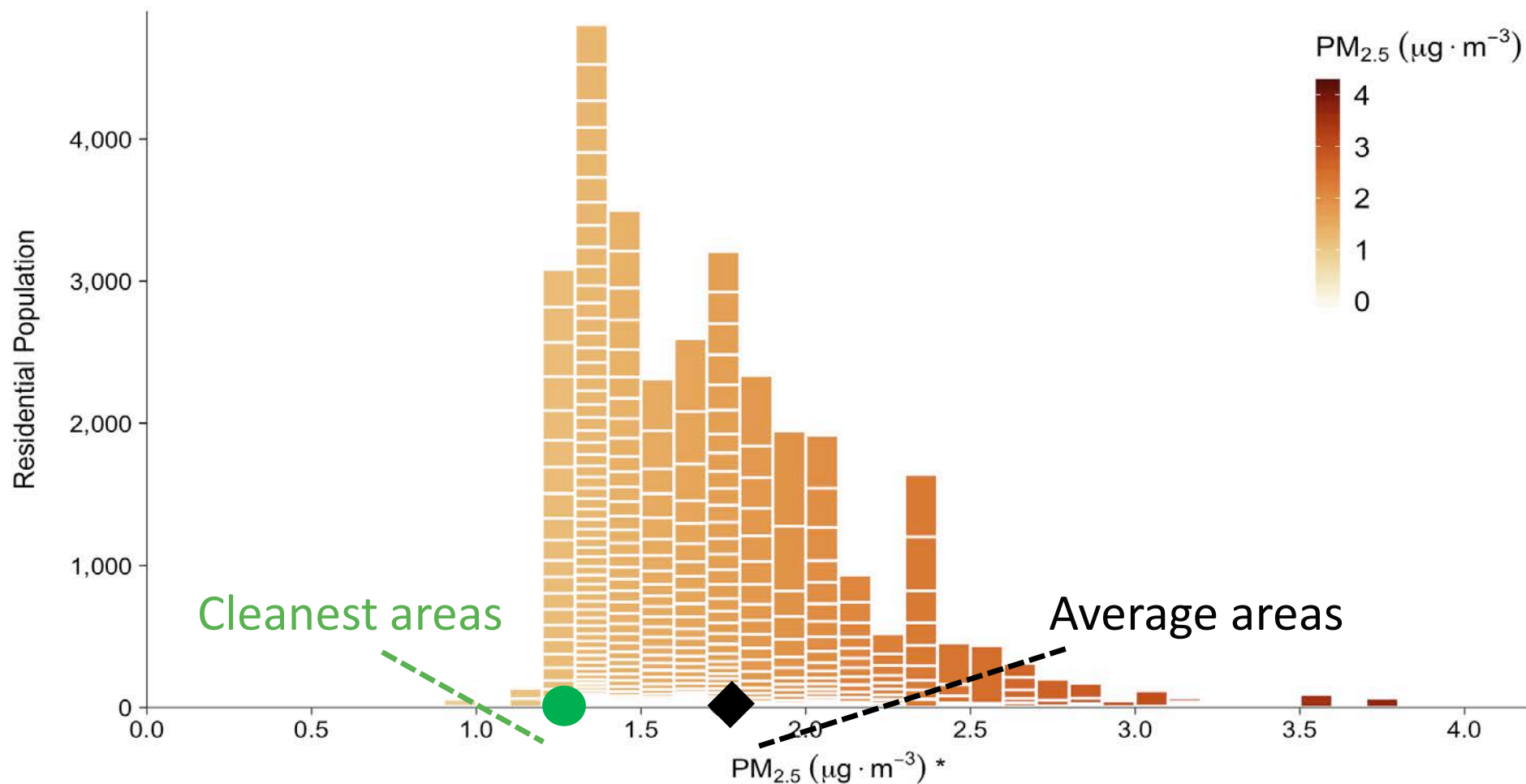
Block by Block

DRAFT 2019-03-04



For any location, we can use the sub-totals to draw pie charts showing the relative impacts of sources A, B, C, etc.

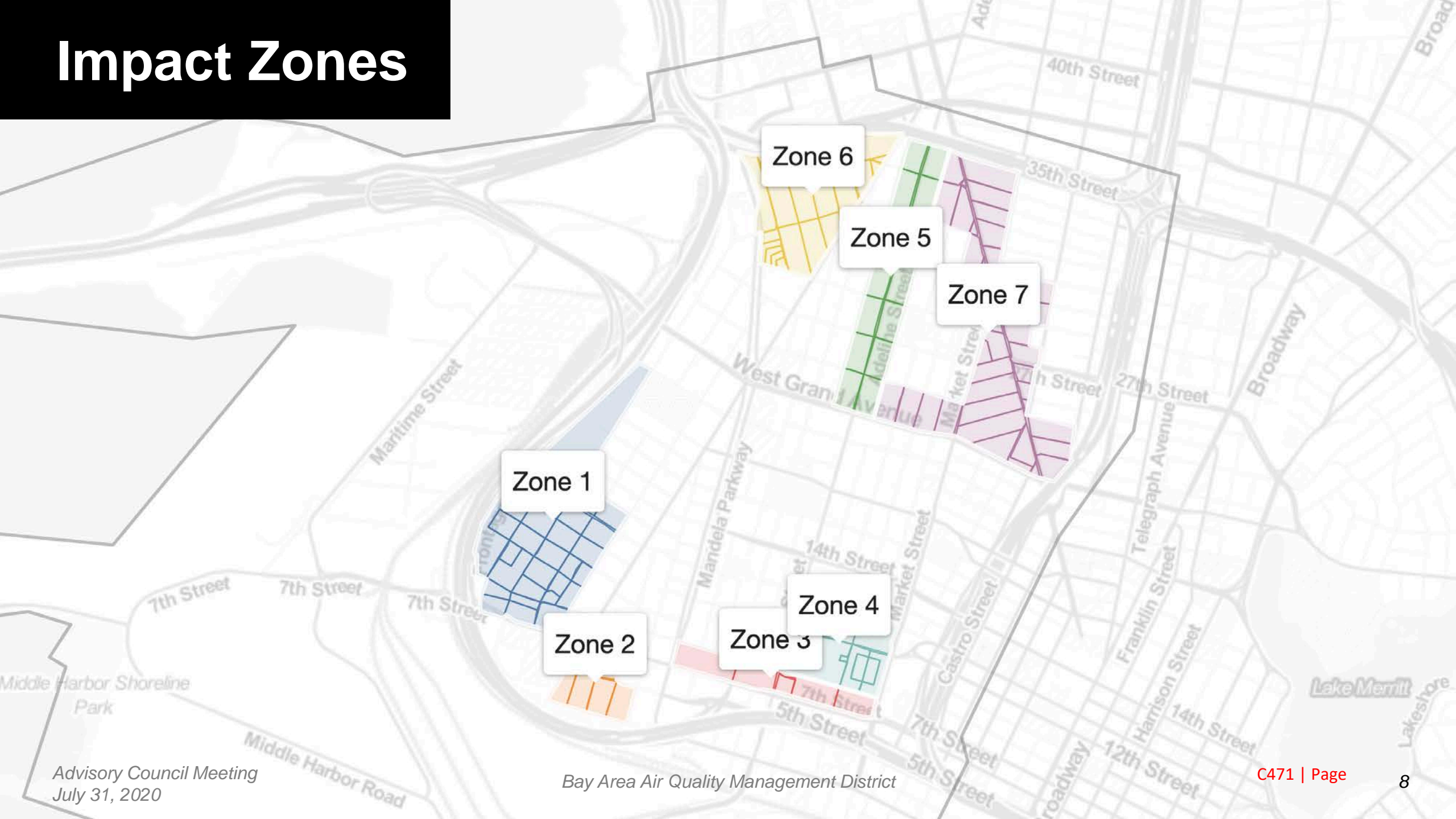
Unequal Impacts: PM_{2.5} Across West Oakland



* Contributed by modeled "present-day" emissions from existing local sources. Impacts from sources outside West Oakland not included.

DRAFT 2019-08-16

Impact Zones

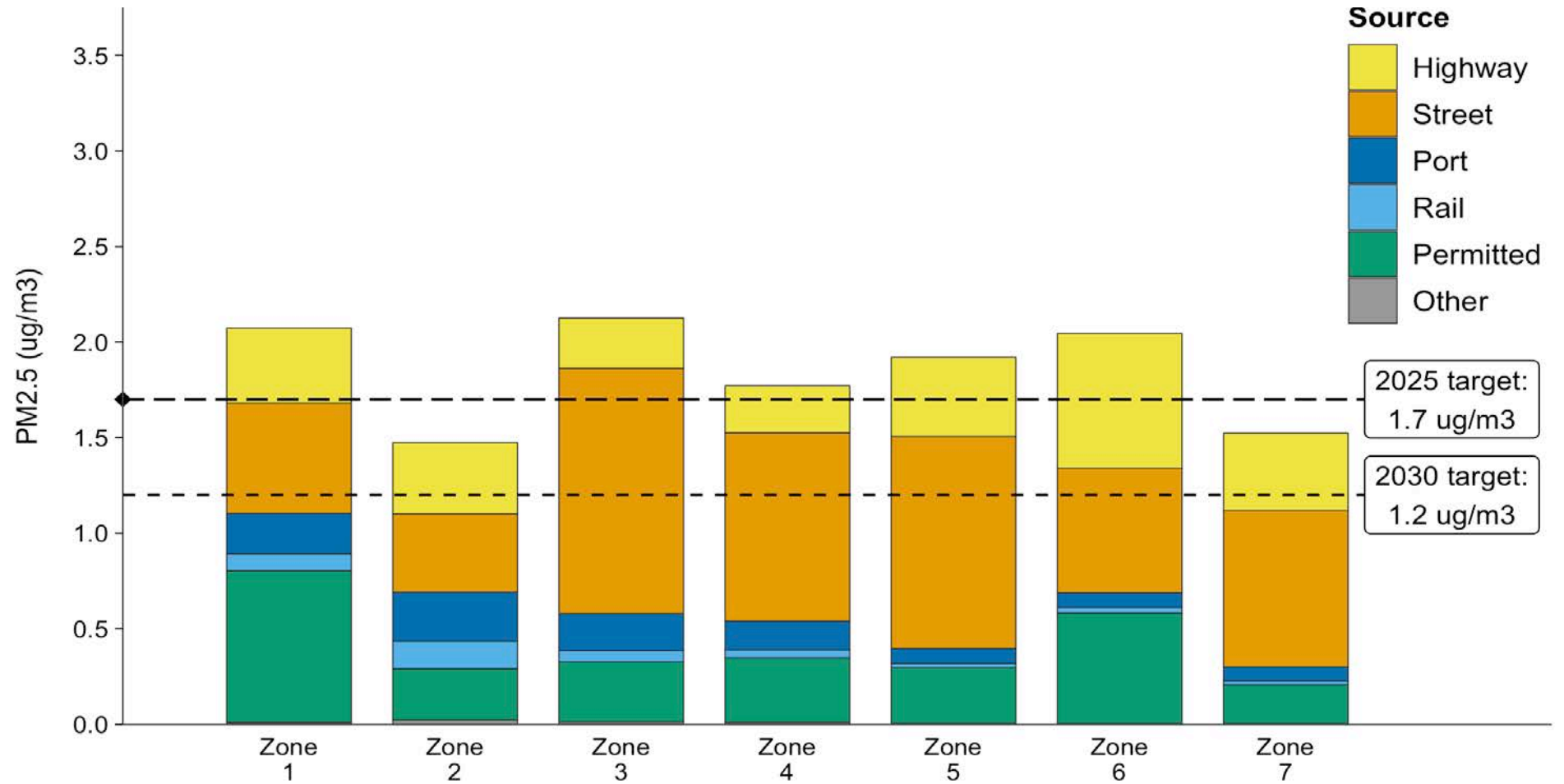


Targets and Source Contributions for PM_{2.5}

Targets:

2025 – Today's *average* residential neighborhood

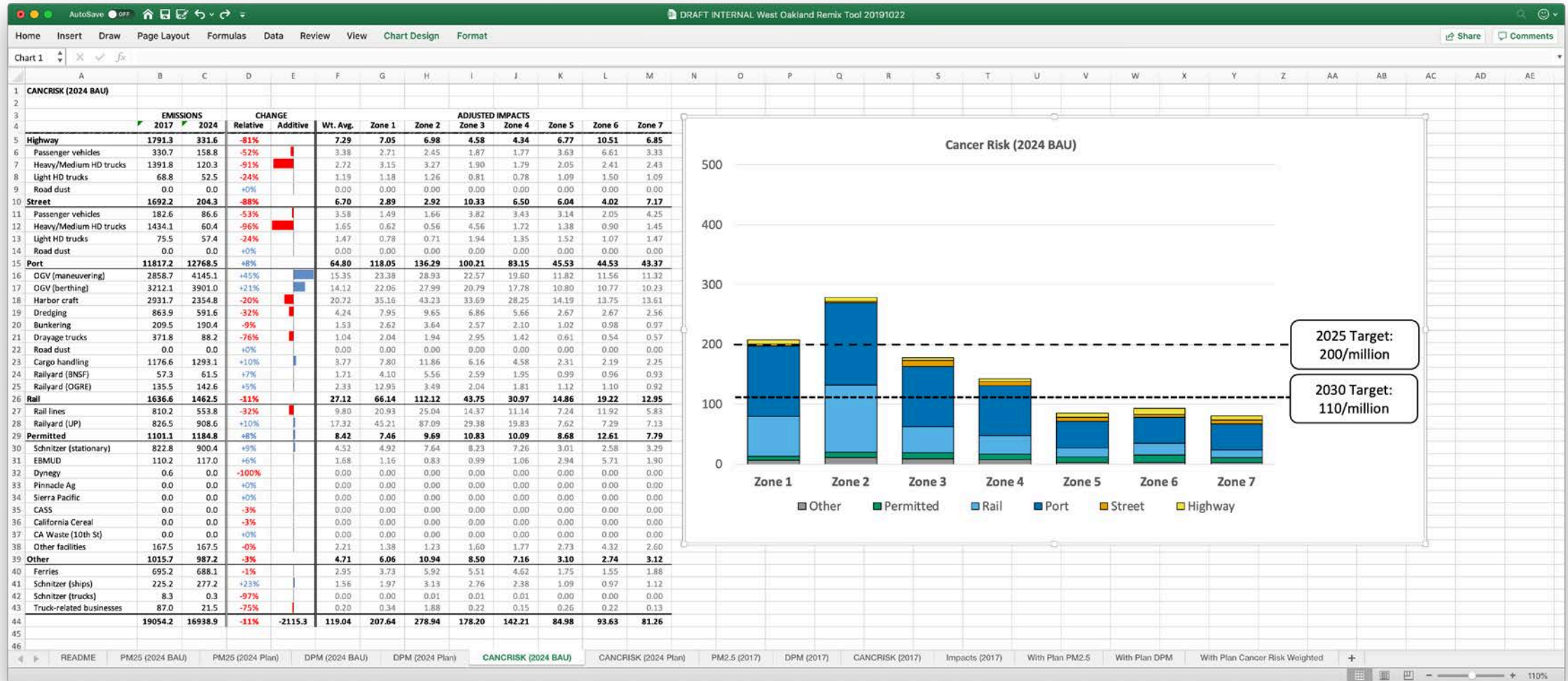
2030 – Today's *cleanest* residential neighborhood



* Contributed by emissions from modeled local sources. Impacts from sources outside West Oakland not included.

DRAFT 2019-08-16

Finding Solutions: "Scenario Tool"





Large Industrial Sources: Chevron Richmond Refinery

Modeling Study



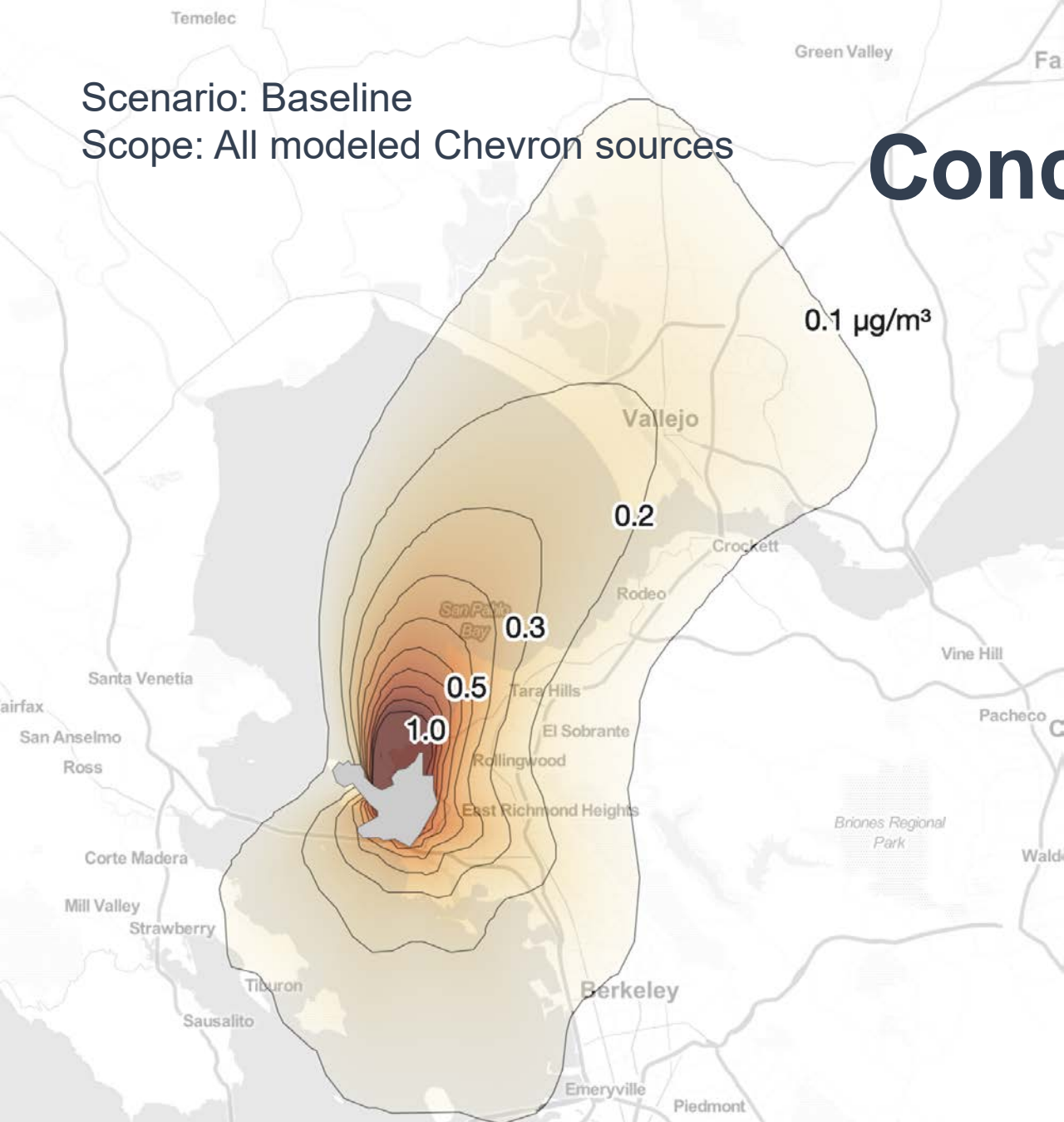
- **Scope:** Tracking directly emitted (primary) PM_{2.5}
 - From all permitted sources at Chevron, including the Fluidized Catalytic Cracking Unit (FCCU)

- **Scenarios:**
 1. Baseline = existing emissions
 2. Additional FCCU emission reductions

- **Approach:** Track plumes with the CALPUFF air quality model to map concentrations (2016-2018)

Scenario: Baseline
Scope: All modeled Chevron sources

Chevron PM_{2.5} Concentration Impacts by Area



- Modeled annual-average, primary PM_{2.5} concentrations from all sources at Chevron
- Baseline scenario
- Measured annual-average PM_{2.5} at nearby San Pablo site: about 8-10 µg/m³*

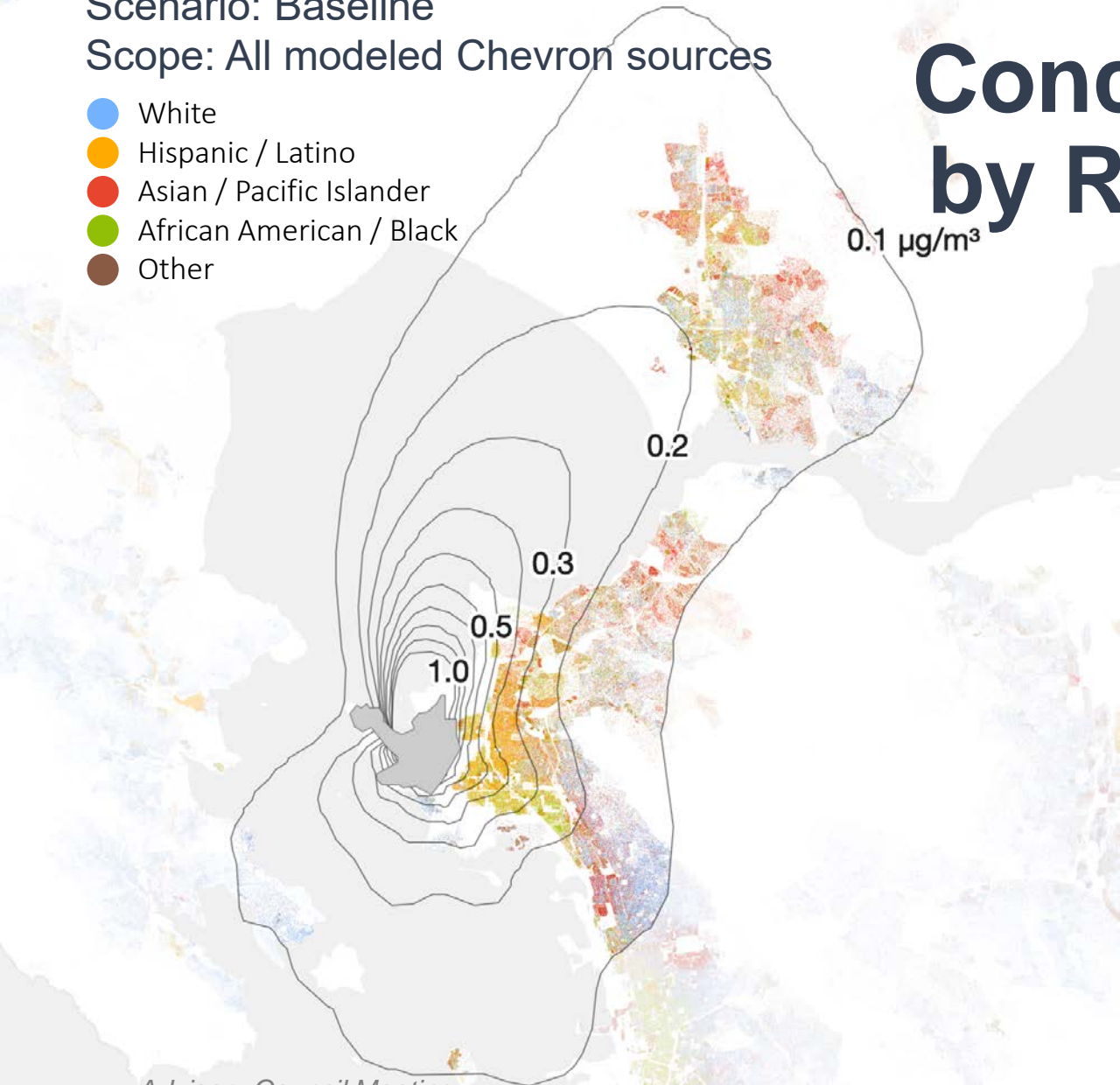
* Excluding 2017-2018 wildfire days; about 8-13 mg/m³ including wildfire days



Chevron PM_{2.5} Concentration Impacts by Residents Exposed

Scenario: Baseline
Scope: All modeled Chevron sources

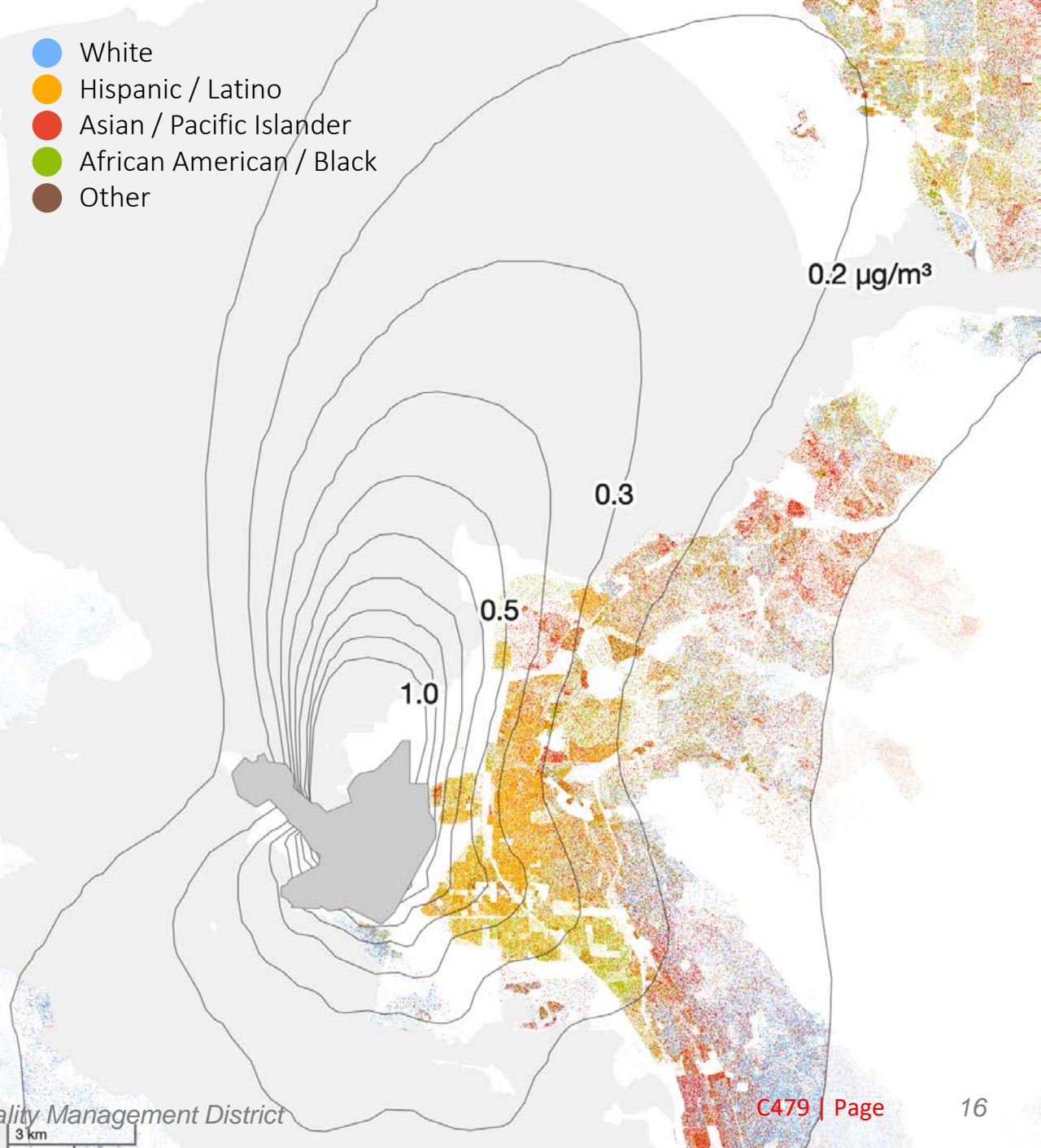
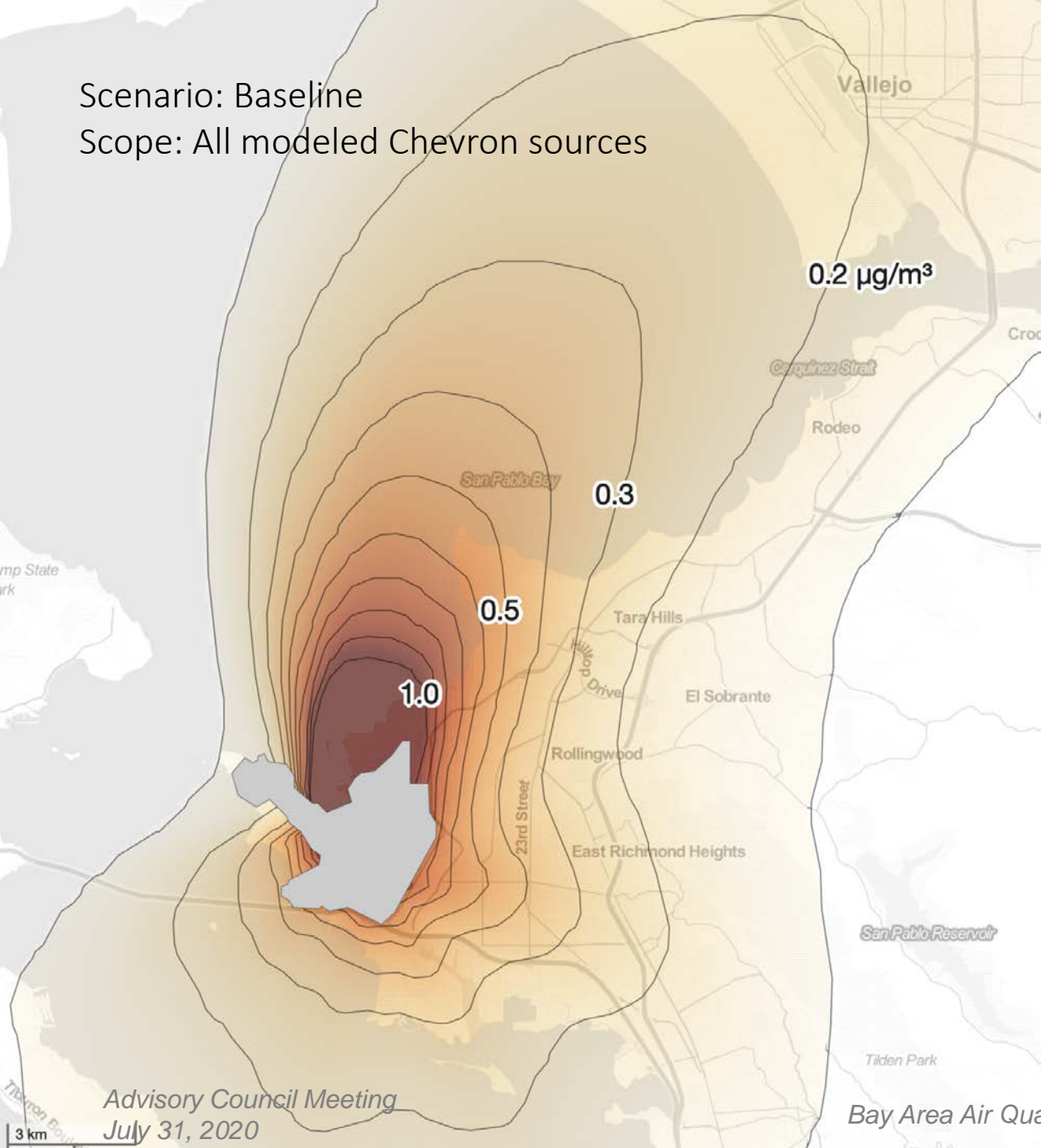
- White
- Hispanic / Latino
- Asian / Pacific Islander
- African American / Black
- Other



- Each color dot represents one person
- Colors are muted outside the 0.1 µg/m³ contour, “the plume”
- Almost half a million people (~449,000) in the plume

Scenario: Baseline
 Scope: All modeled Chevron sources

- White
- Hispanic / Latino
- Asian / Pacific Islander
- African American / Black
- Other

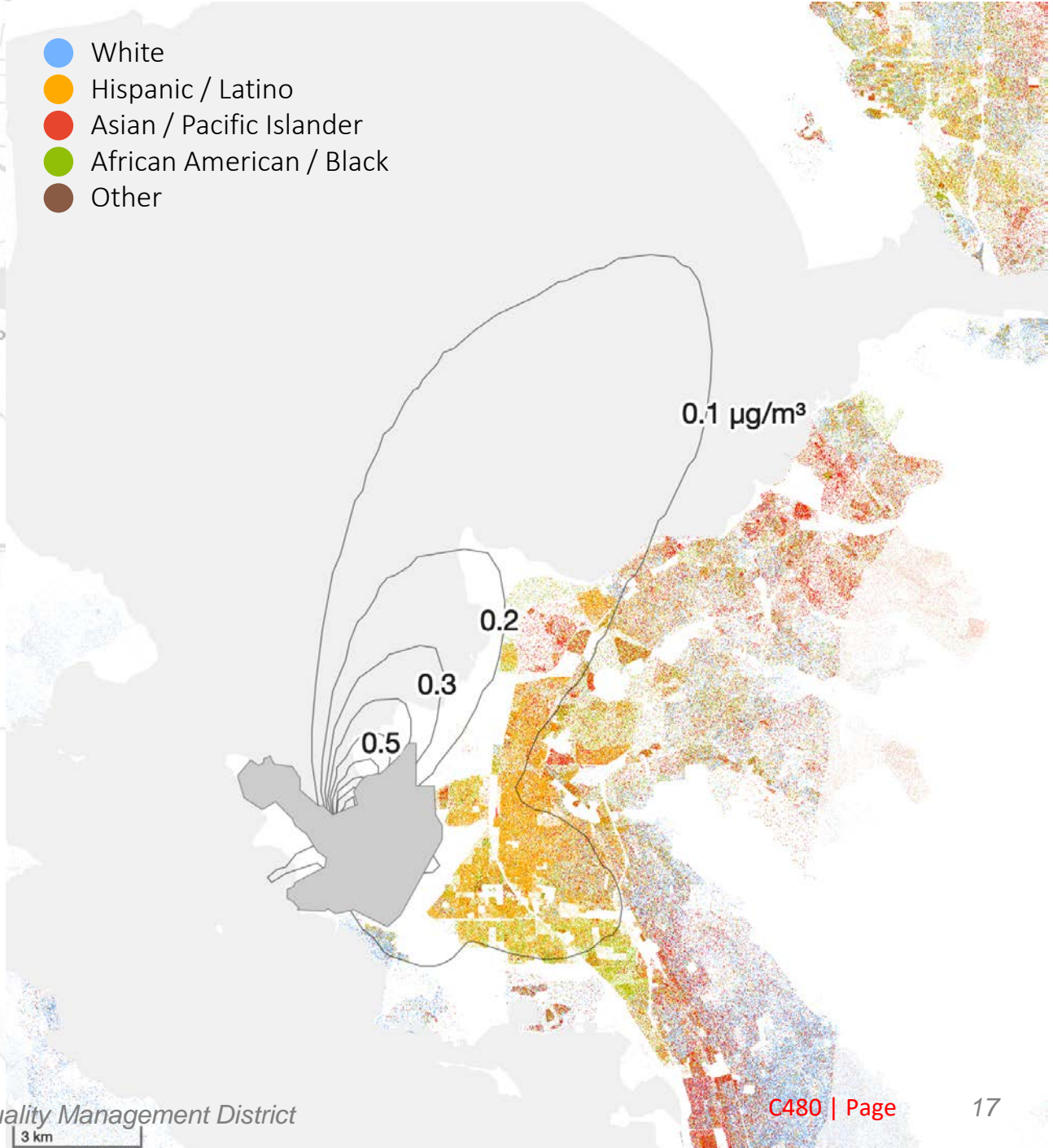
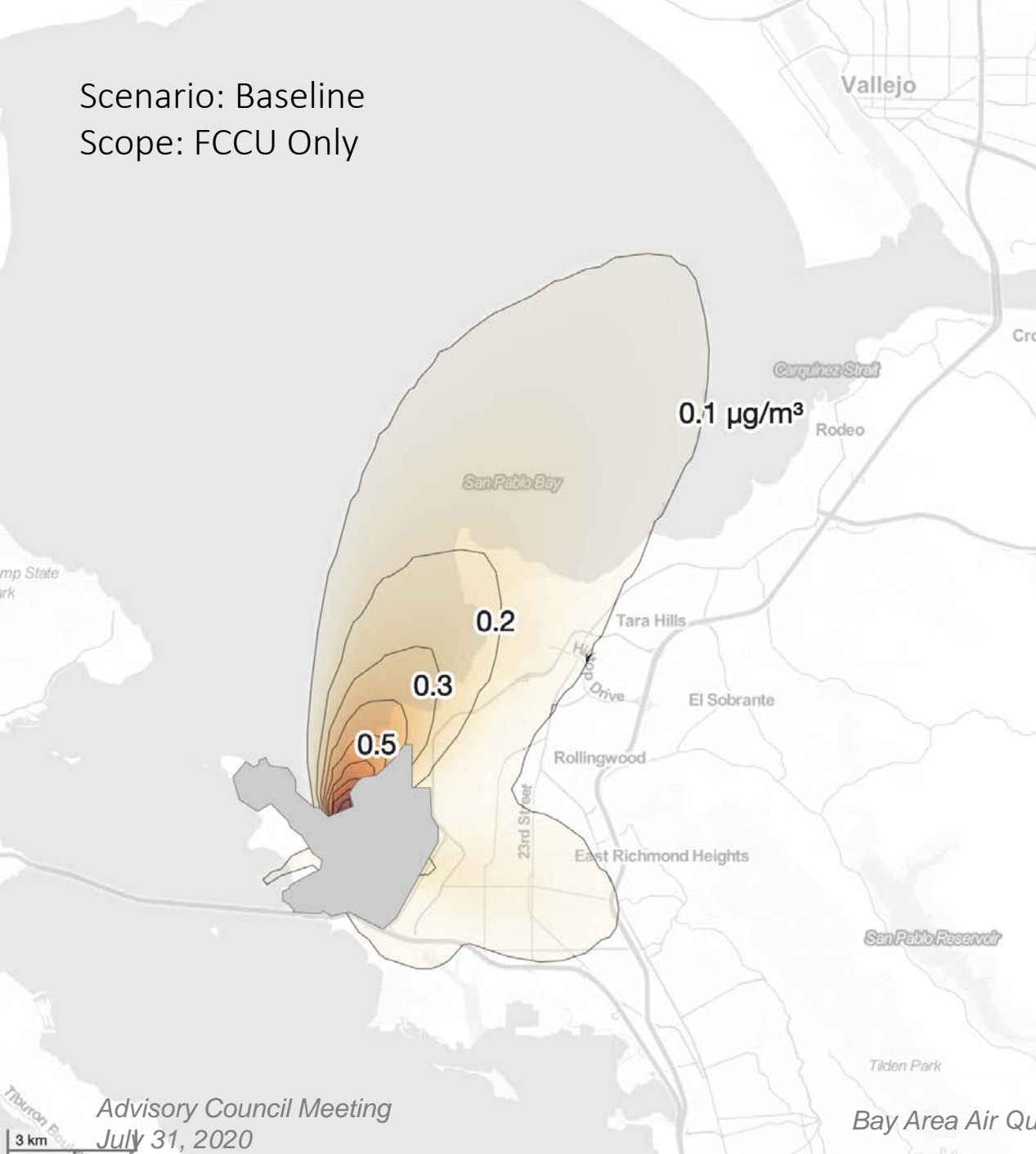


Advisory Council Meeting
 July 31, 2020

Bay Area Air Quality Management District

Scenario: Baseline
 Scope: FCCU Only

- White
- Hispanic / Latino
- Asian / Pacific Islander
- African American / Black
- Other

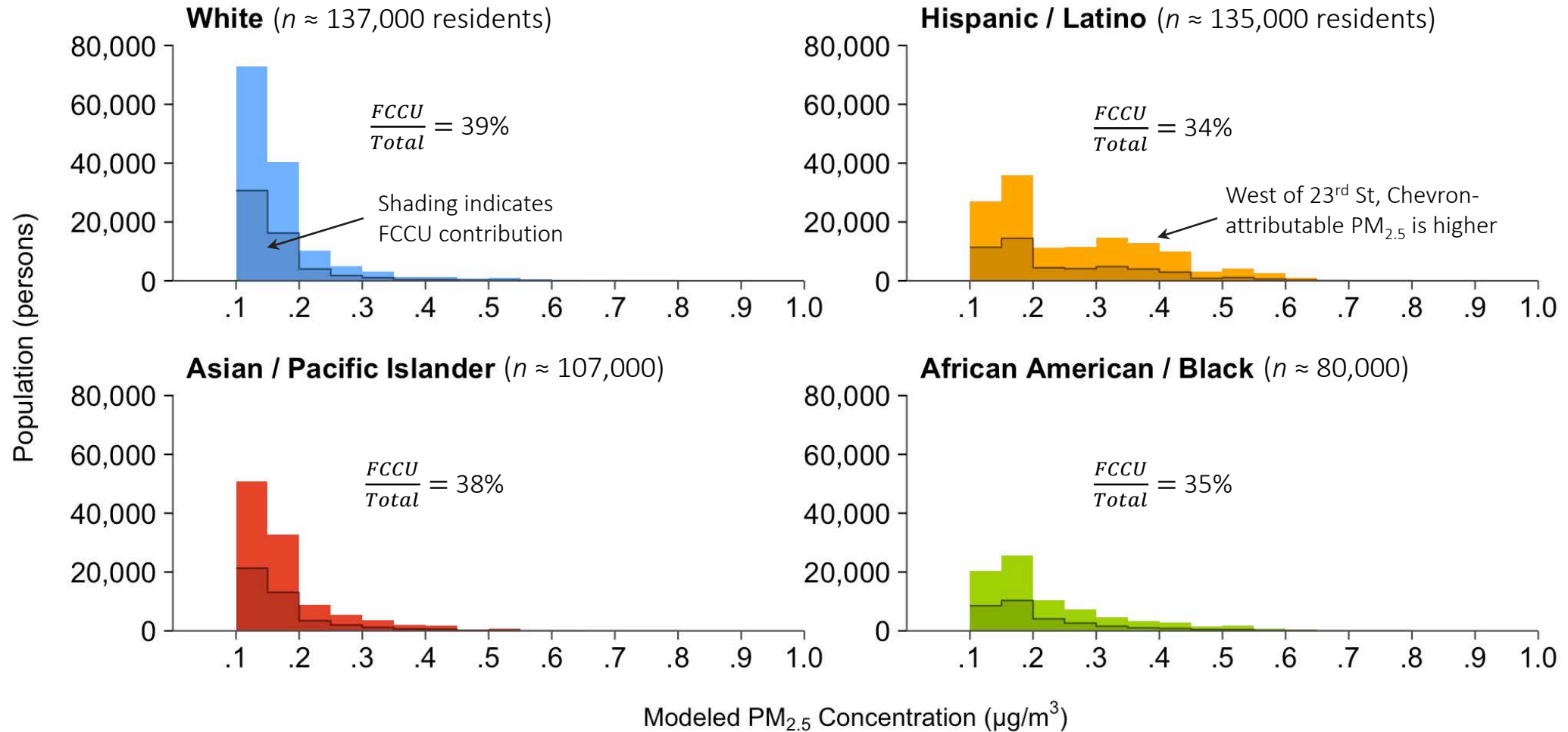


PM_{2.5} Exposures by Race/Ethnicity



Scenario: Baseline

Scope: Census blocks with 0.1 µg/m³ PM_{2.5} or more from Chevron



Next Steps



- Richmond/San Pablo Community Action Plan
- Additional refineries/large industrial facilities
- Methodology for estimating increased adult mortality risk from local sources of PM_{2.5}
 - Highlight risks below the federal standard
 - Based on a recent California epidemiological study
 - Development in partnership with US Environmental Protection Agency (EPA) and the Office of Environmental Health Hazards Assessment (OEHHA)

Summary



- Identify source-contributions to impacts
 - What is responsible?
- Assess equity of impacts to inform decision-making
 - Support agency goal of reducing air pollution inequities
- Work toward highlighting health risks from PM_{2.5} exposures below federal standard
 - Develop a risk framework consistent with “no identified safe level of PM_{2.5}”



Particulate Matter: Spotlight on Health Protection

Appendix D: Advisory Council Information

APPENDIX D: AIR DISTRICT WEBPAGES

Information about the Air District, including air quality forecasts, can be found by visiting <https://www.baaqmd.gov>. In addition, information about the Air District’s Spare the Air program can be found by visiting <https://www.sparetheair.org>.

PARTICULATE MATTER CONFERENCE WEBPAGE

Webcast, audio, presentation materials, reports and meeting minutes for the Advisory Council Particulate Matter Symposium series can be found by visiting <https://www.baaqmd.gov/pmconference>. Meeting dates in the Particulate Matter Symposium series:

- December 9, 2019
- May 12, 2020
- July 31, 2020
- October 9, 2020
- November 9, 2020
- December 16, 2020

AIR DISTRICT ADVISORY COUNCIL AGENDAS, MINUTES AND MEDIA

Additional information about the Air District’s Advisory Council, including Advisory Council member biographies, reports, and meeting information can be found by visiting <https://www.baaqmd.gov/about-the-air-district/advisory-council>.

APPENDIX D: ADVISORY COUNCIL MEMBER BIOGRAPHIES

The following are the biographies of each of the seven Air District Advisory Council members who participated on the Advisory Council over the course of the particulate matter conference series.

CHAIRPERSON STAN HAYES**Principal Emeritus, ENVIRON (now Ramboll)**

Stan Hayes has more than 40 years of experience in environmental science and engineering, with particular emphasis on air impact and health risk analysis for both national ambient air quality standards (NAAQS) and hazardous air pollutant (HAP) purposes, including air quality modeling, strategic and regulatory policy analysis, climate assessment, compliance evaluation, exposure and health risk assessment, and air monitoring and meteorological data analysis.

He is a Fellow of the Air & Waste Management Association, for which he has chaired or co-chaired national and international specialty conferences on climate change, greenhouse gas reporting, and homeland security. Previously, he was a member of the U.S. EPA Science Advisory Board Risk and Technology Review (RTR) Methods Panel.

Chairperson Hayes is the primary author of more than 70 scientific papers and presentations, as well as several hundred technical reports on air-related subjects. He has provided expert testimony before federal, state, and local regulatory agencies and in court. Upon invitation, he has given scientific briefings to members of the California legislature and political leaders elsewhere.

For 25 years, until 2015, he was a Principal with global environmental consulting firm ENVIRON (now Ramboll). He is now emeritus.

Chairperson Hayes earned an M.S. in aeronautics and astronautics and a B.S. in mechanical engineering, both from Stanford University.

VICE CHAIR MICHAEL KLEINMAN**Professor, Environmental Toxicology, Co-Director of the Air Pollution Health Effects Laboratory, Adjunct Professor in College of Medicine, University of California, Irvine**

Michael T. Kleinman is UC Irvine Professor of Environmental Toxicology and Co-Director of the Air Pollution Health Effects Laboratory in the Department of Community and Environmental Medicine, and Adjunct Professor in the College of Medicine.

Dr. Kleinman brings to the Advisory Council expertise in the health effects of air pollution on animals and humans, as well as expertise in the development of analytical techniques for assessing biological and physiological responses to exposure to environmental contaminants and for determining concentrations of important chemical species in air.

The research in Dr. Kleinman's laboratory uses immunological and molecular methods to examine the mechanisms by which toxic agents affect the lung and heart. Current studies include the effects of ambient particles on blood pressure and heart rate in sensitive animal models. Other studies examine the link between asthma and environmental exposures to ambient particles near real-world pollutant sources, such as freeways in Los Angeles. Research focuses on mechanisms of cardiopulmonary injury following inhalation of toxic compounds. State-of-the-art methods are used to evaluate the roles of free radicals and oxidative stress in sensitive human volunteers and laboratory animals. In vitro methods are used to evaluate specific mechanisms.

Dr. Kleinman's current studies involve inhalation exposures to manufactured and combustion-generated nanomaterials as fine and coarse particles using state-of-the-art field exposure systems and real-time physiological monitoring methods. Dr. Kleinman's team is also pursuing how these mechanisms affect pathological and physiological changes in the heart and lungs.

Other interests include analytical and atmospheric chemistry, environmental sampling and analysis, and the application of mathematical and statistical methods to environmental and occupational assessments of exposure and risk.

Dr. Kleinman received a Ph.D. in Environmental Health Sciences from New York University.

TIM LIPMAN

Co-Director, UC Berkeley Transportation Sustainability Research Center

Timothy E. Lipman is an energy and environmental technology, economics, and policy researcher and lecturer with the University of California, Berkeley. He is serving as Co-Director for the campus' Transportation Sustainability Research Center (TSRC), based at the Institute of Transportation Studies, and has also served as Director of the U.S. Department of Energy Pacific Region Clean Energy Application Center (PCEAC).

Dr. Lipman's research focuses on electric-drive vehicles, fuel cell technology, combined heat and power systems, biofuels, renewable energy, and electricity and hydrogen energy systems infrastructure. Most of his research projects are related to the transformation of energy systems to support motor vehicles and buildings, examining how both incremental and "leap frog" technologies can be applied to reduce greenhouse gas emissions and other negative environmental and social impacts of energy use. A central concept for his research is that the electrification of the transportation sector can realize synergy with a concentrated effort to reduce the carbon intensity of the electrical grid, yielding benefits for the electricity sector as well as the expanded use of electricity, hydrogen, and biofuels.

Dr. Lipman received his Ph.D. in Environmental Policy Analysis with the Graduate Group in Ecology at UC Davis (1999). He also has received an M.S. degree in the technology track of the Graduate Group in Transportation Technology and Policy, also at UC Davis (1998), and a B.A. from Stanford University (1990).

JANE C.S. LONG

Associate Director for Energy and Environment, retired, Lawrence Livermore National Lab

Jane Long retired from Lawrence Livermore National Laboratory, where she was the Principal Associate Director at Large, Fellow in the LLNL Center for Global Strategic Research, and the Associate Director for Energy and Environment. She is currently a chairperson of the California Council on Science and Technology's committees on California's Energy Future and assessment of hydraulic fracturing. Her current work involves strategies for dealing with climate change, including reinvention of the energy system, geoengineering, and adaptation.

Dr. Long was the Dean of the Mackay School of Mines, University of Nevada, Reno, and Department Chair for the Energy Resources Technology and the Environmental Research Departments at Lawrence Berkeley National Lab.

Dr. Long is a fellow of the American Association for the Advancement of Science, an Associate of the National Academies of Science (NAS), and a Senior Fellow and council member of the California Council on Science and Technology (CCST) and the Breakthrough Institute.

She holds a bachelor's degree in engineering from Brown University and a master's and Ph.D. from UC Berkeley.

DR. LINDA RUDOLPH

Director, Center for Climate Change and Health

Linda Rudolph is a public health physician with more than four decades of experience in local and state government and non-profit organizations. Currently, Dr. Rudolph is the Director of the Center for Climate Change and Health at the Public Health Institute, where her work has focused on building capacity in local health departments to integrate climate change into public health practice and on supporting health professionals as climate and health champions. She previously served as Deputy Director for Chronic Disease Prevention and Health Promotion in the California Department of Public Health. At CDPH, Dr. Rudolph was the founding chair of the California Health in All Policies Task Force under the auspices of the Strategic Growth Council.

Dr. Rudolph has also served as the Health Officer and Public Health Director for the City of Berkeley, Chief Medical Officer for Medi-Cal Managed Care, and Medical Director for the California Workers' Compensation Division. She is board-certified in Occupational Medicine and worked for many years in occupational health, initially with the Oil, Chemical, and Atomic Workers' International Union.

She received her M.D. from the University of California, San Francisco, and her M.P.H. and B.A. from UC Berkeley.

GINA M. SOLOMON, M.D., M.P.H.

**Clinical Professor, Division of Occupational and Environmental Medicine, UCSF;
Principal Investigator, Public Health Institute**

Gina Solomon is a Clinical Professor in the Division of Occupational and Environmental Medicine at the University of California San Francisco (UCSF) and a Principal Investigator at the Public Health Institute in Oakland, CA. She served as the Deputy Secretary for Science and Health at the California Environmental Protection Agency (CalEPA) from 2012 to 2017, and as a senior scientist at the Natural Resources Defense Council from 1996 to 2012. She was also the director of the occupational and environmental medicine residency program at UCSF, and the co-director of the UCSF Pediatric Environmental Health Specialty Unit.

Dr. Solomon's work has spanned a wide array of areas, including children's environmental health, the health effects of diesel exhaust, reproductive toxicity of environmental chemicals, cumulative impacts and environmental justice, and the use of novel data streams to screen chemicals for toxicity.

She has also done work in exposure science for air pollutants, pesticides, mold, and heavy metals. She conducted environmental exposure studies in Louisiana in the aftermath of Hurricane Katrina and during the Gulf oil spill, published the first study documenting children's exposure to diesel exhaust inside school buses, and served on the Scientific Guidance Panel for Biomonitoring California, a statewide program to measure contaminants in people. Dr. Solomon has also done work on the health effects of climate change. She published a study documenting the large spike in emergency department visits in California during the 2006 heat wave, and has published work documenting the health costs of climate-related events. She works to educate health care professionals and students about the health effects of climate change.

During her tenure at CalEPA, Dr. Solomon advised the Secretary on a wide range of issues related to chemicals in consumer products, toxic air contaminants, drinking water contaminants, and pesticides. She was also involved in recommending policy changes in the aftermath of the Chevron Richmond refinery fire. She chaired the California Interagency Refinery Task Force and successfully spearheaded regulations to improve refinery safety in California. Dr. Solomon has served on multiple boards and committees of the National Academies of Science, the U.S. EPA Science Advisory Board, and the National Toxicology Program's Board of Scientific Counselors. She also serves on the U.S. EPA Board of Scientific Counselors Chemical Safety for Sustainability subcommittee.

Dr. Solomon received her bachelor's degree from Brown University, her M.D. from Yale University, and completed her M.P.H. and her residency and fellowship training in internal medicine and occupational and environmental medicine at Harvard University.

SEVERIN BORENSTEIN

**E.T. Grether Professor of Business Administration and Public Policy, Haas School of Business;
Research Associate, Energy Institute**

Severin Borenstein is E.T. Grether Professor of Business Administration and Public Policy at the Haas School of Business and a Research Associate of the Energy Institute at Haas. He is an affiliated professor in the Agricultural and Resource Economics department and the Energy and Resources Group at UC Berkeley. He is also Director emeritus of the University of California Energy Institute and the Energy Institute at Haas.

Dr. Borenstein has been a research associate of the National Bureau of Economic Research (NBER), in Cambridge, MA, since 1992 and served as co-Director of NBER's research project on e-commerce in 1999-2000. Prior to coming to Haas in 1996, he taught at the University of Michigan and University of California at Davis. Borenstein's research focuses broadly on business competition, strategy, and regulation. He has published extensively on airline, oil and gasoline, and electricity markets, as well as on insurance, e-commerce, mining, natural gas, and other industries. Borenstein's recent research has focused on competition and profitability in the airline industry, the impact of oil prices on gasoline markets, alternative models of retail electricity pricing, and the economics of renewable energy and climate change.

He is currently a co-editor of the *Journal of the Association of Environmental and Resource Economists*. From 1997 to 2003, Dr. Borenstein was a member of the Governing Board of the California Power Exchange. He served on the California Attorney General's gasoline price taskforce in 1999-2000. In 2010-11, Borenstein was a member of U.S. Secretary of Transportation Ray LaHood's Future of Aviation Advisory Committee. In 2012-13, he served on the Emissions Market Assessment Committee, which advised the California Air Resources Board on the operation of California's Cap and Trade market for greenhouse gases.

He received his undergraduate degree from UC Berkeley and Ph.D. in economics from MIT.

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 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



Advisory Council Discussion with Experts

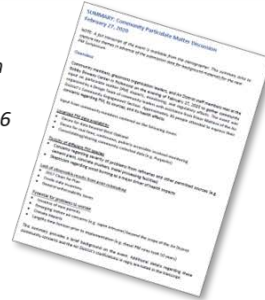
DECEMBER 9, 2019

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



JUNE 29 – JULY 2, 2020

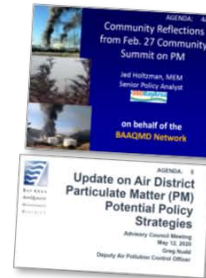
Air and Waste Management Association Panel: Developing a Path Forward for PM_{2.5} Regulation in the Bay Area

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

MAY 12, 2020

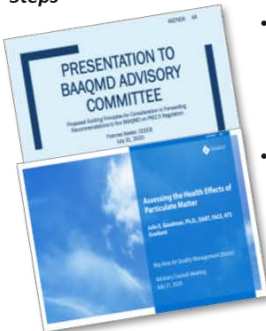
Advisory Council Meeting: Community Presentations and Air District Update on PM Potential Policy Strategies

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



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

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.

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. These statements of evidence 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 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 exposures substantially above standards.

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

PMRS4) More stringent standards are 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 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.

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/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.

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.

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, and justifies greater efforts to reduce other sources of PM to reduce overall health risk.

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

NEWLY ADDED PMRS11) Ultrafine particles (UFP) which are present in the air in large numbers, pose a health risk. They generally enter the body through the lungs but translocate to essentially all organs. Compared to fine particles (PM_{2.5}), they cause more pulmonary inflammation and are retained longer in the lung.

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

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:

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 increased exposure, 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 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, NO_x, NH₃, and SO₂).

F7) PM reduction strategies will need to address multiple source categories.

RECOMMENDED ACTIONS

The Advisory Council, through feedback from experts, and observation, have identified several actions the Air District can take to reduce particulate matter in the region. These actions include, but are not limited to, the following:

AIR DISTRICT-WIDE

RA1) Establish a PM_{2.5} target consistent with other findings (e.g. from an annual average of 10 µg/m³ to as low as 8 µg/m³).

MONITORING

RA2) Continue working to make air quality data more accessible and timely. Partner with effective formats such as Purple Air.

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

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

TECHNOLOGY

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

ENFORCEMENT

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.

~~**RA6) Increase staff to implement/enforce Rule 11-18.**~~

~~**RA7) Devote more staff to risk assessment for air toxics programs like Rule 11-18.**~~

ASSESSMENT, INVENTORY, & MODELING

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

PLANNING

RA8) Develop Air District PM strategic 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.

RULE DEVELOPMENT

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

RA13) Modify permitting regulations to address hyper-localized hotspot health risks.

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

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

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

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

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

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

ENGINEERING/PERMITTING

RA20) Take into account cumulative impact in permitting.

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

FUNDING

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

RA23) Seek federal funding for electrification infrastructure.

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

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.

AUTHORITY

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

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

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

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

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

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

ADDITIONAL RECOMMENDED ACTIONS

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.

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

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

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.

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.)

**ANNOTATED BIBLIOGRAPHY FOR PARTICULATE MATTER
REDUCTION STATEMENTS AND FRAMEWORK****PARTICULATE MATTER REDUCTION STATEMENTS**

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.

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 exposures substantially above standards.

References:

- **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.

- **Environmental Protection Agency: Air Quality Designations for the 2012 Primary Annual Fine Particle (PM_{2.5}) National Ambient Air Quality Standards (NAAQS); Final Rule**, available online at <https://www.govinfo.gov/content/pkg/FR-2015-01-15/pdf/2015-00021.pdf>.

This Federal Register document records the U.S. EPA's designations of areas in attainment and nonattainment of NAAQS in 2012, prior to the onset of more frequent wildfires. The San

Francisco Bay Area Air Basin is shown as being in attainment of the 2012 Annual PM_{2.5} NAAQS.

- **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 µg/m³ standard with mortality risk at potential standards of 9 µg/m³, 10 µg/m³, and 11 µg/m³, 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/m³ would save more than 143,000 lives in one decade compared to the current 12µg/m³ 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/m³ NAAQS threshold.

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

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); 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/m³ standard with mortality risk at potential standards of 9 µg/m³, 10 µg/m³, and 11 µg/m³, 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 are 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).

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/m³ standard with mortality risk at potential standards of 9 µg/m³, 10 µg/m³, and 11 µg/m³, and Table 3-8 calculates the number of lives that could be spared and the potential percent reduction in mortality at these lower PM 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.”

PMRS5) 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.

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 may be warranted; 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.

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).**

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 µg/m³ standard with mortality risk at potential standards of 9 µg/m³, 10 µg/m³, and 11 µg/m³, 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/m³ would save more than 143,000 lives in one decade compared to the current 12µg/m³ 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/m³ NAAQS threshold.

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.

References:

- 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).

- **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.

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.

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 quintiles. The most polluted areas of 1981 remained the most polluted areas of 2016.

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, and justifies greater efforts to reduce other 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.

- **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.

NEWLY ADDED PMRS10) 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.

NEWLY ADDED PMRS11) Ultrafine particles (UFP) which are present in the air in large numbers, pose a health risk. They generally enter the body through the lungs but translocate to essentially all organs. Compared to fine particles (PM_{2.5}), they cause more pulmonary inflammation 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.

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

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).**

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.

3.3.2.2., Table 3-7 compares mortality associated with PM_{2.5} exposure at the current 12 µg/m³ standard with mortality risk at potential standards of 9 µg/m³, 10 µg/m³, and 11 µg/m³, 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/m³ would save more than 143,000 lives in one decade compared to the current 12µg/m³ 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/m³ NAAQS threshold.

FRAMEWORK

F1) Where the Air District has authority, move quickly to take maximal feasible action.

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) 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 increased exposure, 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 should consider 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 consider emission reduction measures for both primary PM and secondary PM formed in the air (e.g., emissions of precursor ROG, NO_x, NH₃, and SO₂).

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.

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).