



Clean Air Region Initiative AQ Bootcamp for the Balkan Countries

Szeged, Hungary
September 8-9, 2021



Combustion Particle Pollution Exposures, Adverse Health Outcomes, and Mitigation/Control

Alberto Ayala, PhD, MSE

Executive Director, Sacramento Metropolitan Air Quality Management District
Adjunct Professor, Mechanical and Aerospace Engineering, West Virginia University
(FMR) Deputy Executive Officer, California Air Resources Board



ACKNOWLEDGEMENTS



Environmental Research Advances

Ambient Combustion Ultrafine Particles and Health

Doug Brugge, PhD • Christina H. Fuller, ScD
Editors



Chapter 13

ULTRAFINE PARTICLES AND AIR POLLUTION POLICY

*Alberto Ayala, PhD, MSE**

Air Pollution Control Officer and Executive Director,
Sacramento Metropolitan Air Quality Management District;
Adjunct Professor, Mechanical and Aerospace Engineering, West Virginia University;
(FRM) Deputy Executive Officer, California Air Resources Board

PREFACE

A Mile Wide and an Inch Deep

We will be discussing the policy landscape in the U.S. related to ultrafine particles (UFP), air pollution, and actions taken by environmental authorities to deal with this problem. After defining UFP and covering some background information, we will use the subject of internal combustion engine emissions of particulate matter (PM) to introduce the policy actions in the U.S. related to UFP. The story will lead us down the path of regulatory standards, other policy instruments, and research spanning the last three decades and conclude with a brief discussion of UFP in ambient air, traffic-related UFP emissions, and near-road air quality.

Any treatment of public policy for environmental protection necessarily will be broad and touch on many interrelated subjects that, threaded together, begin to form the basis for articulation of regulatory and other requirements. Many of those subjects can be highly technical and scientific in nature, requiring specific expertise to be able to draw policy-relevant conclusions. A policy discussion on air pollution and UFP is no exception. While in this chapter we will deal with a broad array of specialized topics such as air pollution, health effects, particle theory, measurements, experimentation, instrumentation, internal combustion, technology, public process, and government bureaucracy; we can do it only superficially. The reader is forewarned to be ready and is highly encouraged, especially if she is a current student, to conduct additional reading and research on these subjects. We will explore the policy landscape in the U.S. and Europe related to UFP pollution and discover that while there may be a lack of

* Corresponding Author's E-mail: AAyala@airquality.org or betoayala@yahoo.com

Scope of the PM Pollution Challenge

- 10.2 million premature mortality due to fossil fuel PM2.5
- > 2X World Health Organization estimate
- Fossil fuel = coal, petrol, diesel
- Fossil fuel combustion can be more readily controlled than others sources and precursors of PM2.5 such as dust or wildfire smoke
- This is a call to policymakers to switching to clean energy as soon as possible

Environmental Research 195 (2021) 110754

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres



Global mortality from outdoor fine particle pollution generated by fossil fuel combustion: Results from GEOS-Chem

Karn Vohra^{a,*}, Alina Vodonos^b, Joel Schwartz^b, Eloise A. Marais^{c,1}, Melissa P. Sulprizio^d, Loretta J. Mickley^d

^a School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham, UK
^b Harvard T.H. Chan School of Public Health, Department of Environmental Health, Harvard University, Boston, MA, USA
^c Department of Physics and Astronomy, University of Leicester, Leicester, UK
^d John A. Paulson School of Engineering and Applied Sciences, Harvard University, Cambridge, MA, USA

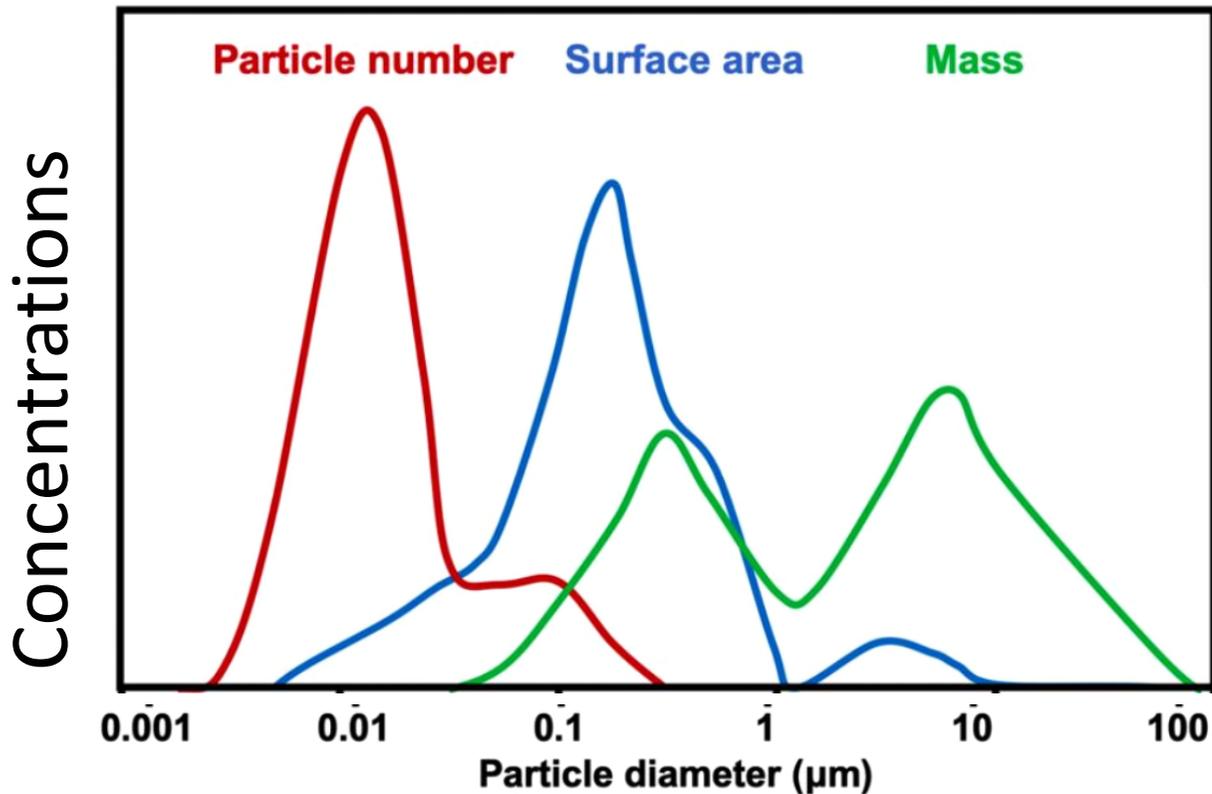
ARTICLE INFO

Keywords:
Particulate matter
Fossil fuel
Mortality
Health impact assessment

ABSTRACT

The burning of fossil fuels – especially coal, petrol, and diesel – is a major source of airborne fine particulate matter (PM_{2.5}), and a key contributor to the global burden of mortality and disease. Previous risk assessments have examined the health response to total PM_{2.5}, not just PM_{2.5} from fossil fuel combustion, and have used a concentration-response function with limited support from the literature and data at both high and low concentrations. This assessment examines mortality associated with PM_{2.5} from only fossil fuel combustion, making use of a recent meta-analysis of newer studies with a wider range of exposure. We also estimated mortality due to

DEFINITIONS



PM10

PM2.5

PM0.1 (ultrafine particles)

PM0.05 (nanoparticles)



“a laboratory for clean air policy from which the whole country can benefit” – US Congress, 1970 Clean Air Act

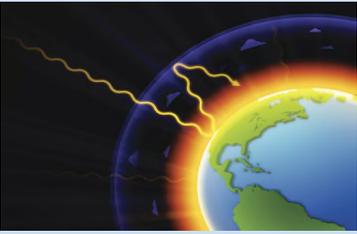
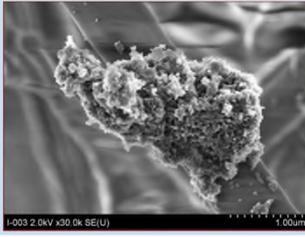
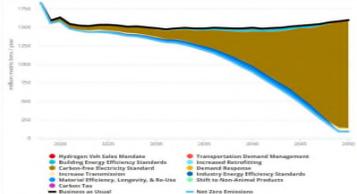
1940s	First deadly air pollution episodes	“Donora smog” of 1948	1970s	Emission controls (tailpipe catalyst)		2000s	Greenhouse Gases	
1950s	First Air Pollution Control Agency	Los Angeles County Air Pollution Control District	1980s	Exposure: “hot spots” and toxics		2010s	Carbon Cap&Trade, vehicle electrification	
1960s	First emission regulations		1990s	Diesel		2020s	?...transformation, 2035, 2040, 2050 decarbonization	

Figure 4: Policies' contribution to abatement of U.S. electricity emissions in the net zero pathway ... [x] ENERGY INNOVATION

Predominant Sources of Ultrafine Particles (UFP)

- Traffic exhaust/internal combustion engines
- Ship terminals/Ports
- Industry
- Home heating and cooking
- Crop burning and wildfires

COMPOSITION of UFP Air Pollution

Although unique “markers” do not exist, there is extensive evidence of composition

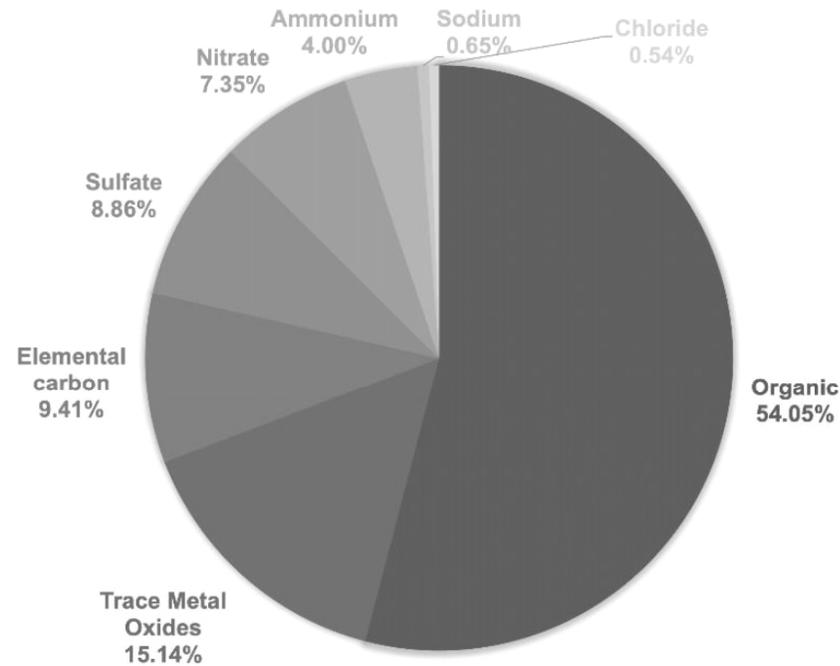


Figure 8. Composition of particles between 56 and 100 nm from seven sites in Southern California (adapted from Cass et al. 2000).

Source Attribution of UFP Air Pollution

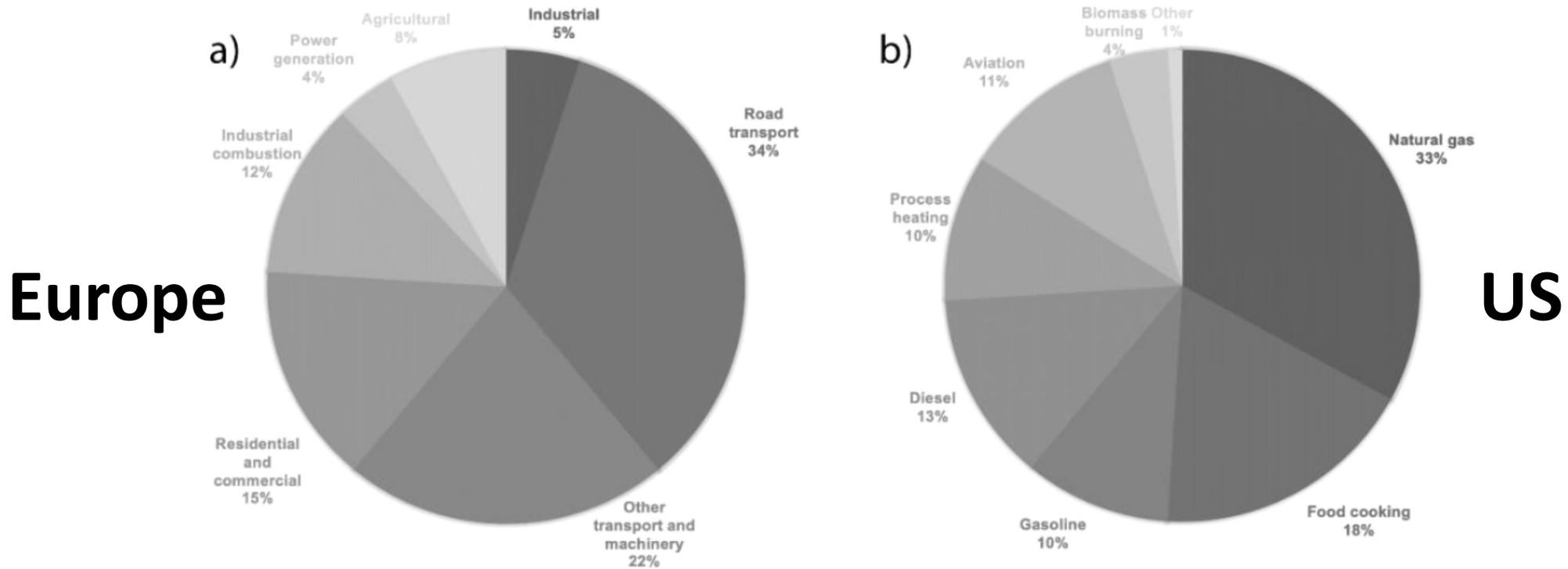


Figure 11. Estimated source contributions to UFP mass for the European Union (a; Union 2013) and weighted by population for 39 cities across the United States (b; Veneck, Yu, and Kleeman 2019).

Adverse Short-term Effects of Exposure to Ultrafine Particle Pollution

- Airway inflammation
- Lung function
- Systemic inflammation
- Oxidative stress
- Genotoxicity
- Thrombogenicity
- Heart rate variability
- Vascular function
- Arrhythmia
- Neurotoxicity
- Alzheimer and other neurological effects on urban children and young adults

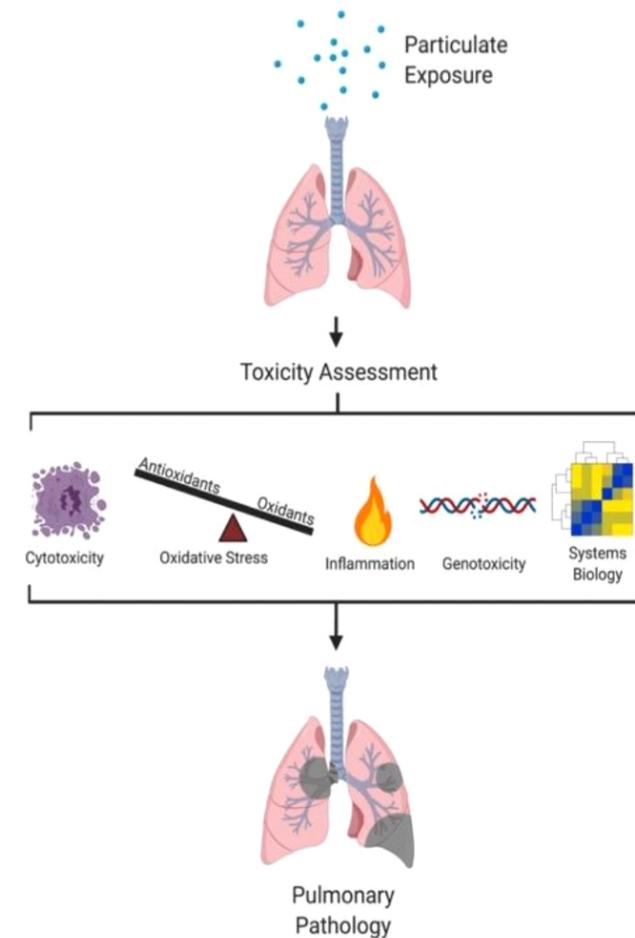
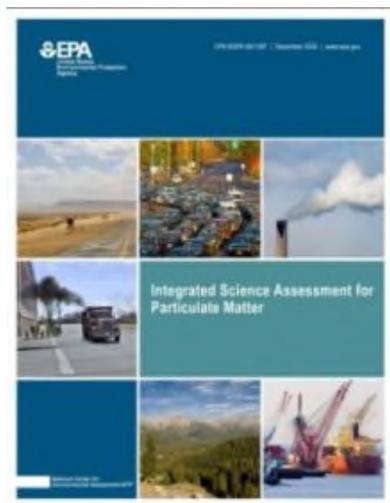


Figure 2. Exposure pathway and potential outcomes of inhaled combustion derived particulate matter.

Adverse health effects and exposure to PM



Causality Determinations for Exposures to PM				
Size Fraction	Short-term Exposures		Long-term Exposures	
	Health Category	Causality Determination	Outcome	Causality Determination
PM2.5	Cardiovascular Effects	Causal	Cardiovascular Effects	Causal
	Respiratory Effects	Likely to be Causal	Respiratory Effects	Likely to be Causal
	Central Nervous System Mortality	Inadequate Causal	Reproductive and Developmental Cancer Mortality	Suggestive Suggestive Causal
PM10-2.5	Cardiovascular Effects	Suggestive	Cardiovascular Effects	Inadequate
	Respiratory Effects	Suggestive	Respiratory Effects	Inadequate
	Central Nervous System Mortality	Inadequate Suggestive	Reproductive and Developmental Cancer Mortality	Inadequate Inadequate Inadequate
Ultrafine PM	Cardiovascular Effects	Suggestive	All Outcomes	Inadequate
	Respiratory Effects	Suggestive		
	Central Nervous System Mortality	Inadequate Inadequate		

U.S. EPA. Integrated Science Assessment for Particulate Matter (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/139F, 2009. <http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=216546>



Today, we are at a classic glass half full or half-empty stage. The evidence for concern has grown substantially, but falls short of being convincing to regulators for enacting general policies, especially at the national level.

Local Interventions to Abate Exposure to Particle Pollution

- Active transportation and measures that reduce combustion vehicle use
- Electric mobility (zero emission vehicles)
- Land use zoning tool – ordinance that separates the living uses from potentially harmful uses
- Land use guidance for siting sensitive receptors – the “500 feet rule”
- Vegetative barriers
- Combustion of structures and vegetation
- Noise Wall Barriers
- Landscaped zoning buffers
- Performance zoning
- Sustainable zoning – Leadership in Environmental and Energy Design (LEED)
- Building design codes
- Building electrification - *taking combustion out of the home*

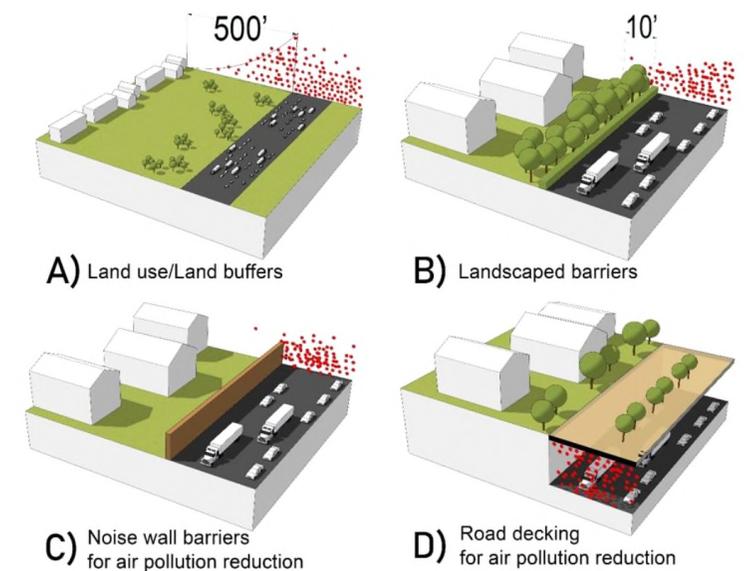
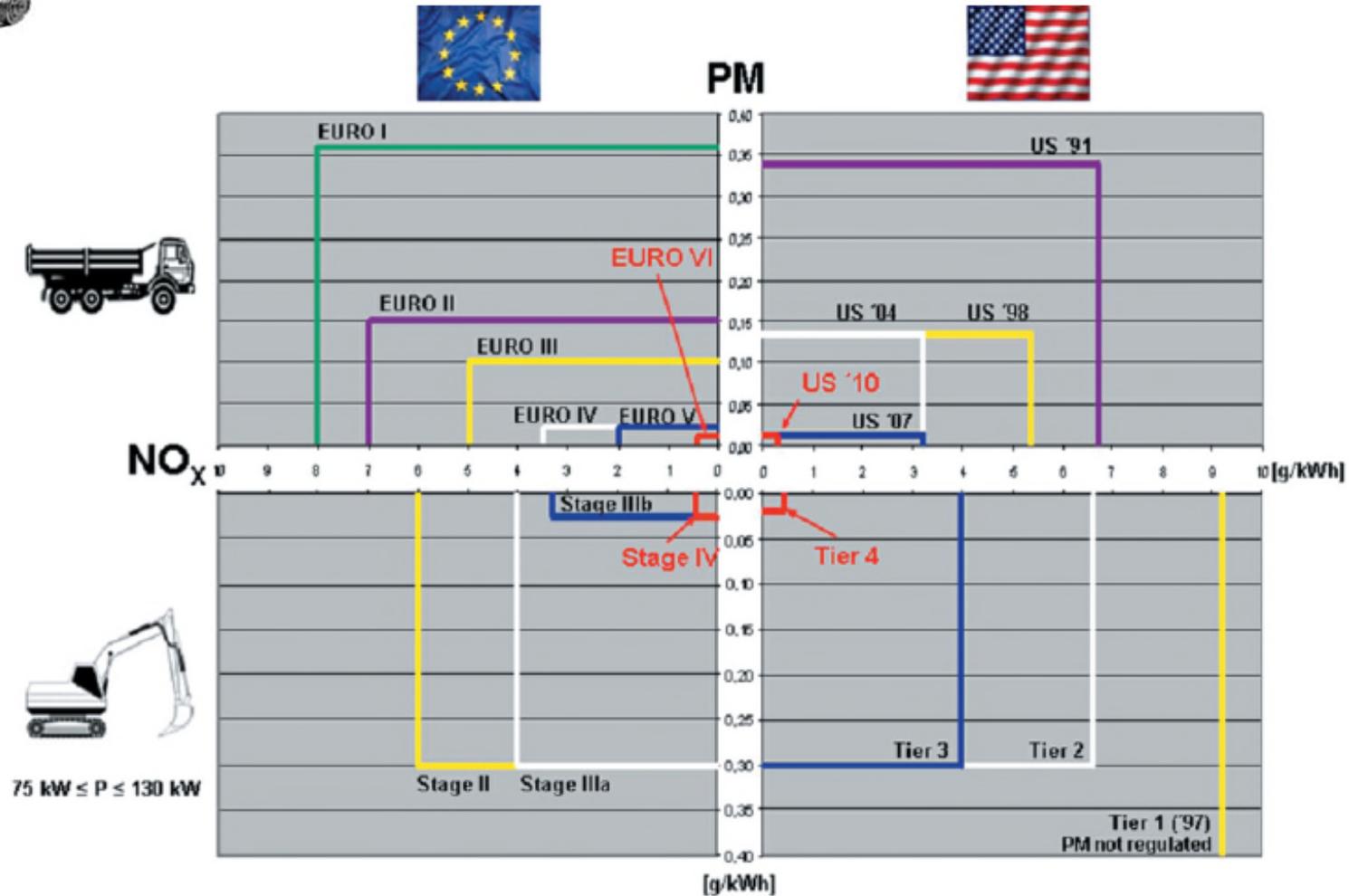


Figure 1. Mitigation strategies at the urban scale.

Regulation of PM Emissions from Transport



Emission standards for new engines/vehicles are the most important regulatory policy instrument for air quality



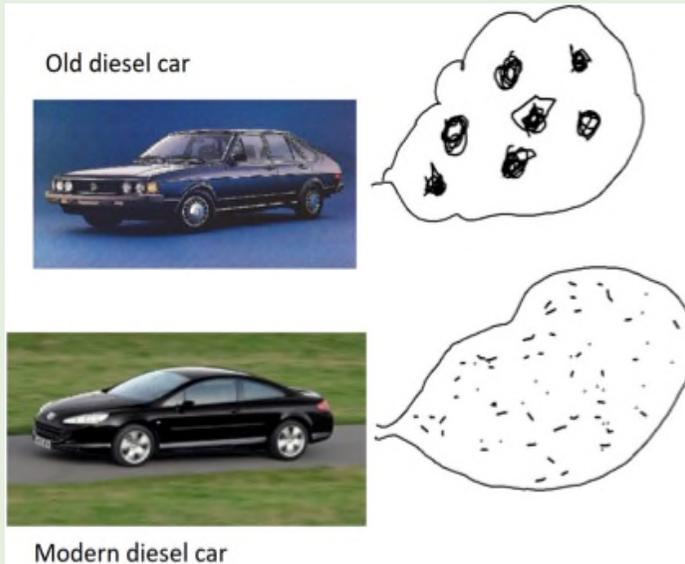
Two key policy drivers emerged in 1996 and 1998

“Houston, We have a Problem!”



Bagley et al. 1996. HEI Research Report # 76.
<http://pubs.healtheffects.org/view.php?id=124>

HEI 1996 Study showed higher total number of particles from newer engine (1991) than from older technology engine (1988)

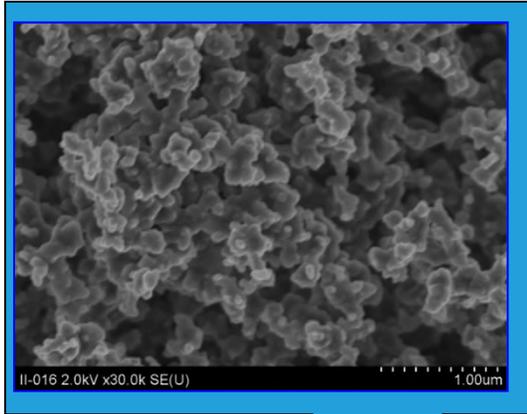
The image shows the cover of a staff report from the California Environmental Protection Agency Air Resources Board. The title is "INITIAL STATEMENT OF REASONS FOR RULEMAKING" and the subject is "PROPOSED IDENTIFICATION OF DIESEL EXHAUST AS A TOXIC AIR CONTAMINANT".
A photograph of a white semi-truck with a large plume of black diesel exhaust coming from its tailpipe. Two people in blue shirts are standing in the foreground, looking at the truck.

Diesel formally recognized as a known carcinogen to humans by way of inhalation pathway

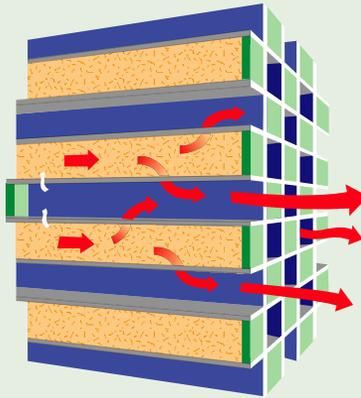
Legal “identification” requires a plan for “mitigation” of exposure risk

Diesel Particle Filter (DPF) - *game changer* for Emission Control

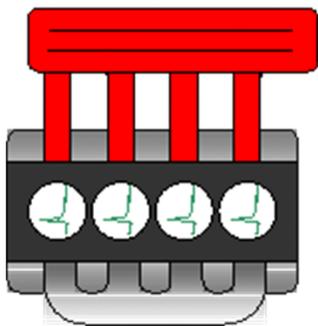
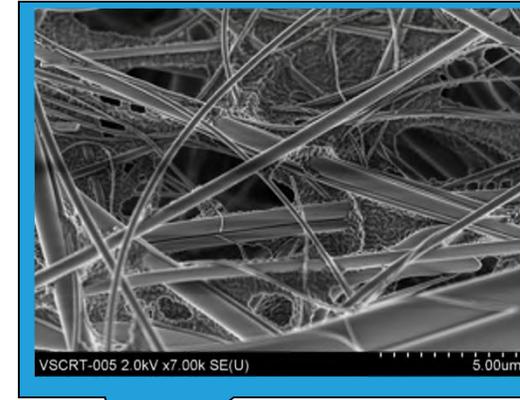
Pre-DPF soot or black carbon



DPF



Post-DPF clean sample

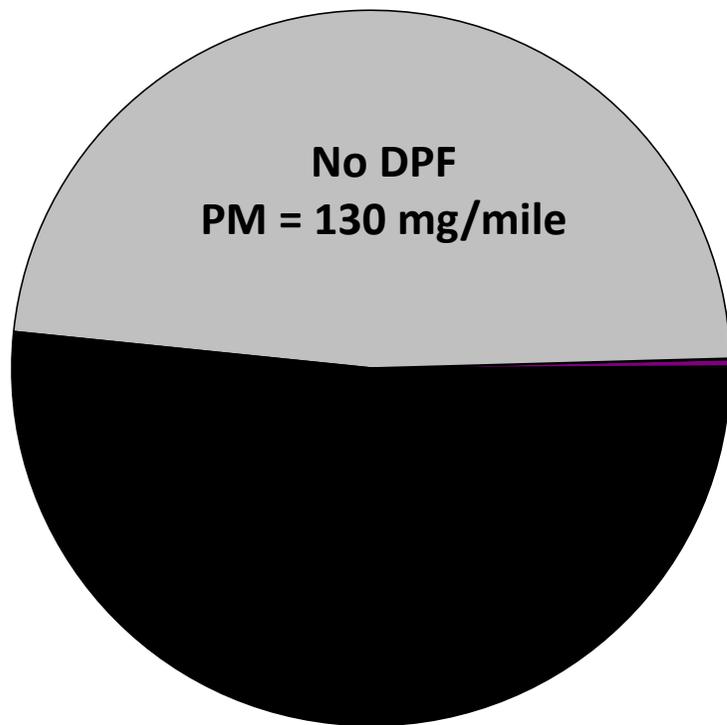


Diesel Engine

Exhaust

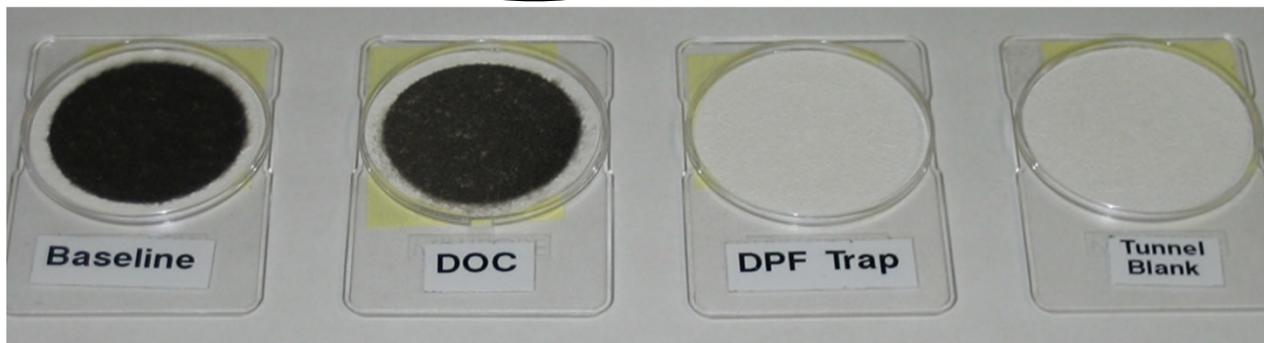
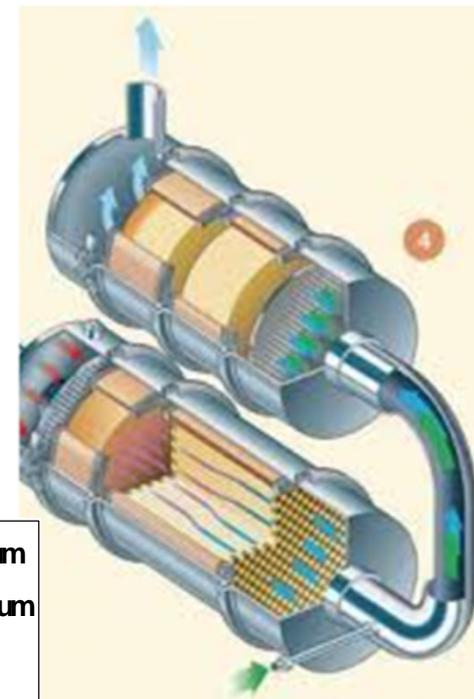
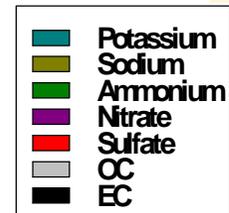
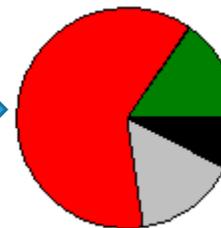
SEM images courtesy of Dr. D. Su, Fritz-Haber Institute

CHEMICAL COMPOSITION OF PM MASS EMISSIONS



Emission reduction

DPF + NO_x SCR
PM = 17 mg/mile



Emiss. Control Sci. Technol.
DOI 10.1007/s40825-014-0002-7

Similarities and Differences Between “Traditional” and “Clean” Diesel PM

Chris Ruehl · Jorn D. Herner · Seungju Yoon · John F. Collins · Chandan Misra · Kwangsam Na · William H. Robertson · Subhasis Biswas · M.-C. Oliver Chang · Alberto Ayala

DPF can eliminate or generate UFP emissions, depending on various operational factors

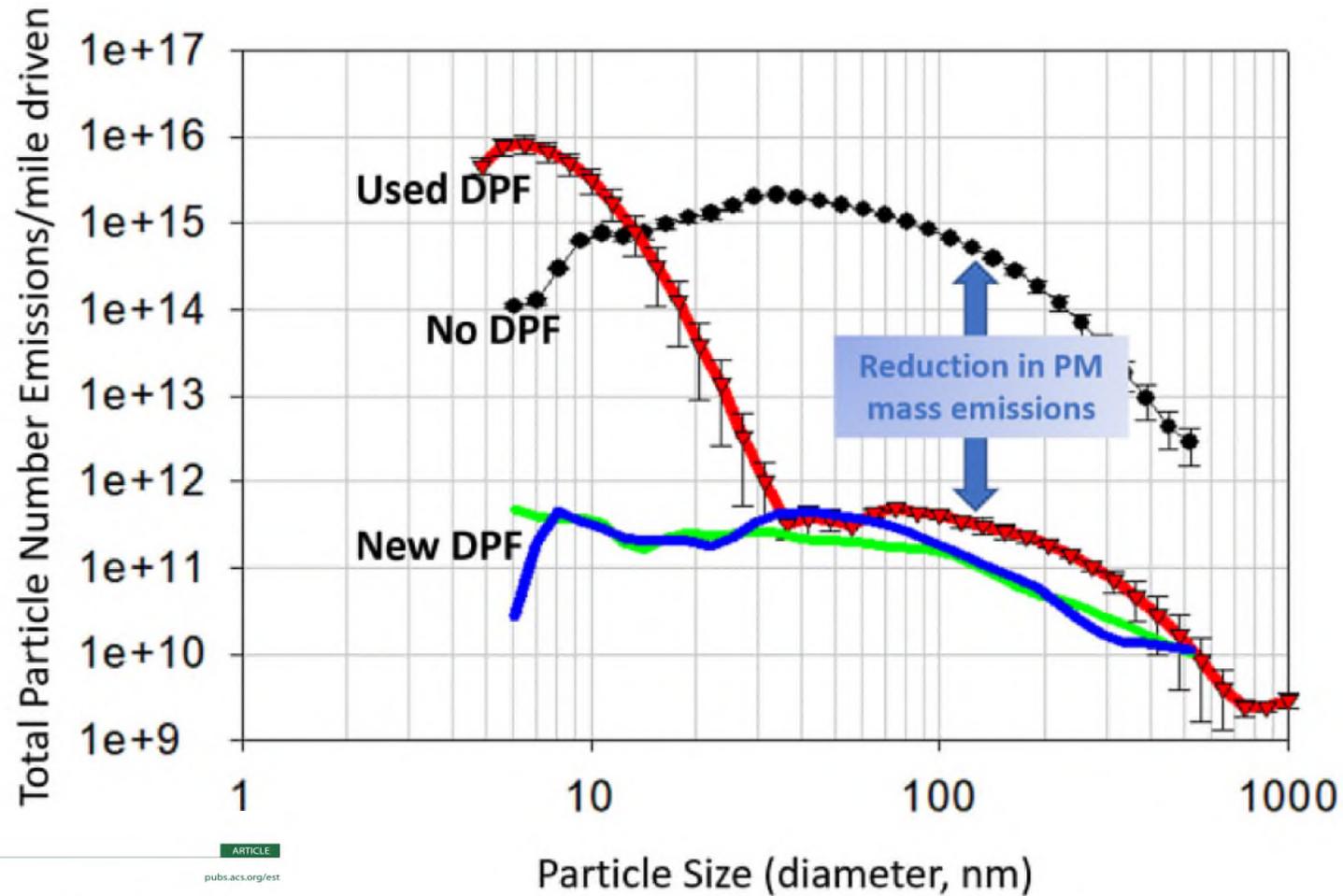


Figure 6 in book reproduced from Hener et al. 2011



The European Ultrafine Particle Number Emission Standard – “first and only”

UNECE
World Forum For Harmonization
of Vehicle Regulations (WP.29)
How it works - How to join it
Fourth Edition



- ❑ Research program under auspices of United Nations
- ❑ ~ 2 decades (~1997-2015) of intense international research collaboration
- ❑ ~12 international laboratories (1 in US – California as “informal” participant)
- ❑ Reference standards shared by all laboratories
- ❑ Cradle-to-grave approach to for standard setting
 - ❑ Definitions, measurement protocols, instruments, regulatory limits, etc.
- ❑ Euro standards include UFP limits, US standards do not
- ❑ We “agree to disagree”



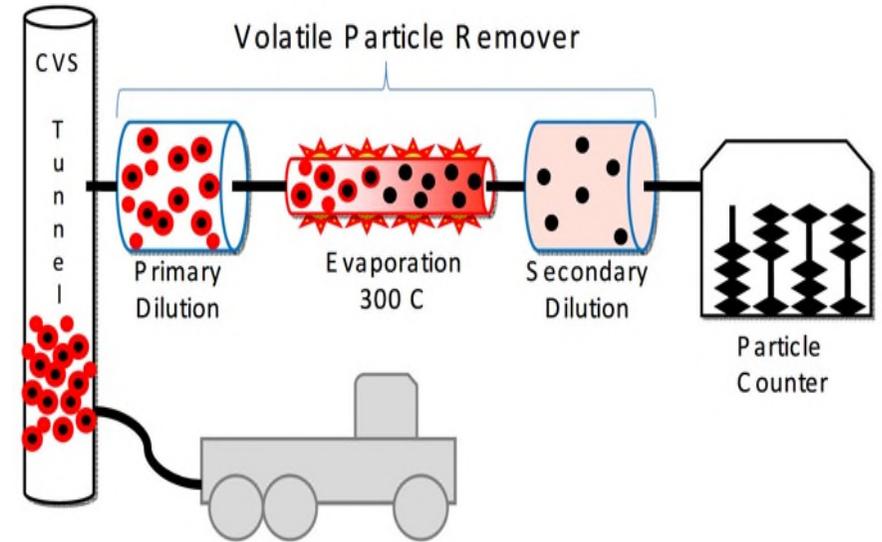
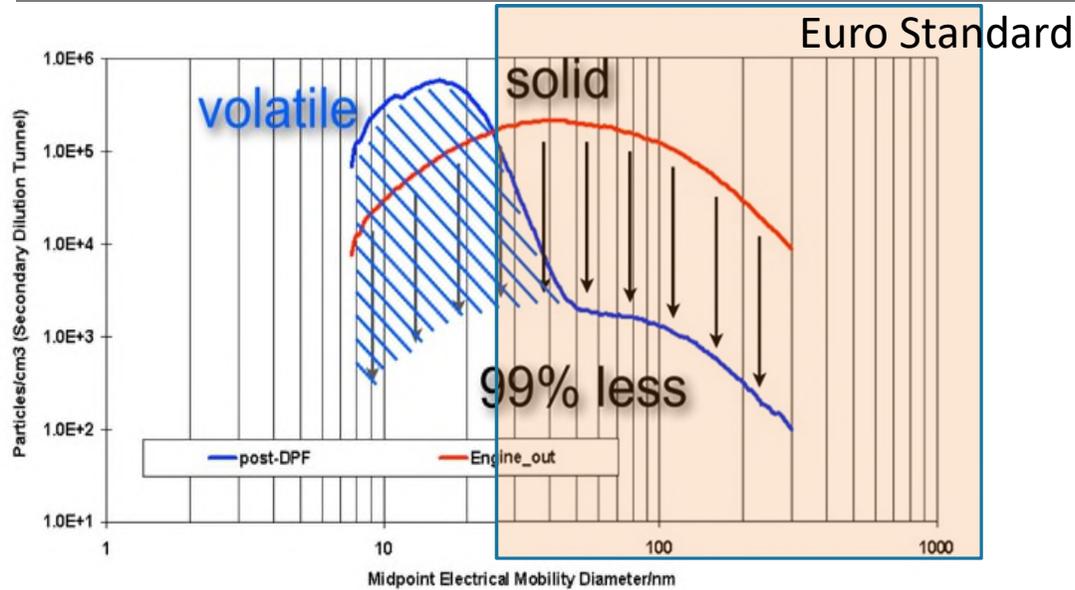
STATE OF CALIFORNIA
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
AIR RESOURCES BOARD

CALIFORNIA'S INFORMAL
PARTICIPATION
IN THE PARTICLE
MEASUREMENT
PROGRAMME (PMP)
LIGHT DUTY
INTER-LABORATORY
CORRELATION
EXERCISE (ILCE_LD)

FINAL RESEARCH REPORT

October 2008

Why did California abandon Euro Particle Number Emission Standards?



...Because of exclusion of toxicologically-relevant volatile fraction of particle emissions

Aerosol Science and Technology, 43:962-969, 2009
Copyright © American Association for Aerosol Research
ISSN: 0278-6826 print / 1521-7388 online
DOI: 10.1080/02786820903074810

Evaluation of the European PMP Methodologies during On-Road and Chassis Dynamometer Testing for DPF Equipped Heavy-Duty Diesel Vehicles

Kent C. Johnson,¹ Thomas D. Durbin,¹ Heejung Jung,¹ Ajay Chaudhary,¹ David R. Cocker III,¹ Jorn D. Herber,² William H. Robertson,² Tao Huai,² Alberto Ayala,² and David Kittelson³

¹University of California, College of Engineering, Center for Environ. Res. Technol. (CE-CERT), Riverside, California, USA

²California Air Resources Board (CARB), Sacramento, California, USA

³University of Minnesota, Department of Mechanical Engineering, Minneapolis, Minnesota, USA





Renewable “Electrons and Molecules” Powering Mobility Forward



ELECTRIC VEHICLES
Calif. will make Uber and Lyft nearly all-EV by 2030
David Farnis, E&E News reporter • Published: Tuesday, November 24, 2020

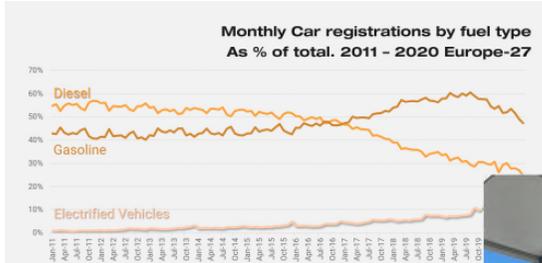


CAL MATTERS

ENVIRONMENT

Newsom orders ban of new gas-powered cars by 2035

BY RACHEL BECKER, SEPTEMBER 23, 2020
UPDATED ON SEPTEMBER 25, 2020



JATO

October 29, 2020

In September 2020, for the first time in European history, registrations for electrified vehicles overtook diesel



**100% renewable energy
by 2045 in California**



Thank you



916.600.5004
AAyala@airquality.org