Current Status of Condensable Particulate Matter (CPM) for Gas-Fired Combustion Systems

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Air & Waste Management Association

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Topics

- What is CPM?
- CPM Emission Factor for Gas Combustion – Current Status
- Current CPM Emission Factor Impacts on Air Permitting
- Alternative CPM Emission Factor
- Summary

What is CPM?

Particulate Matter (PM) Emissions

CPM

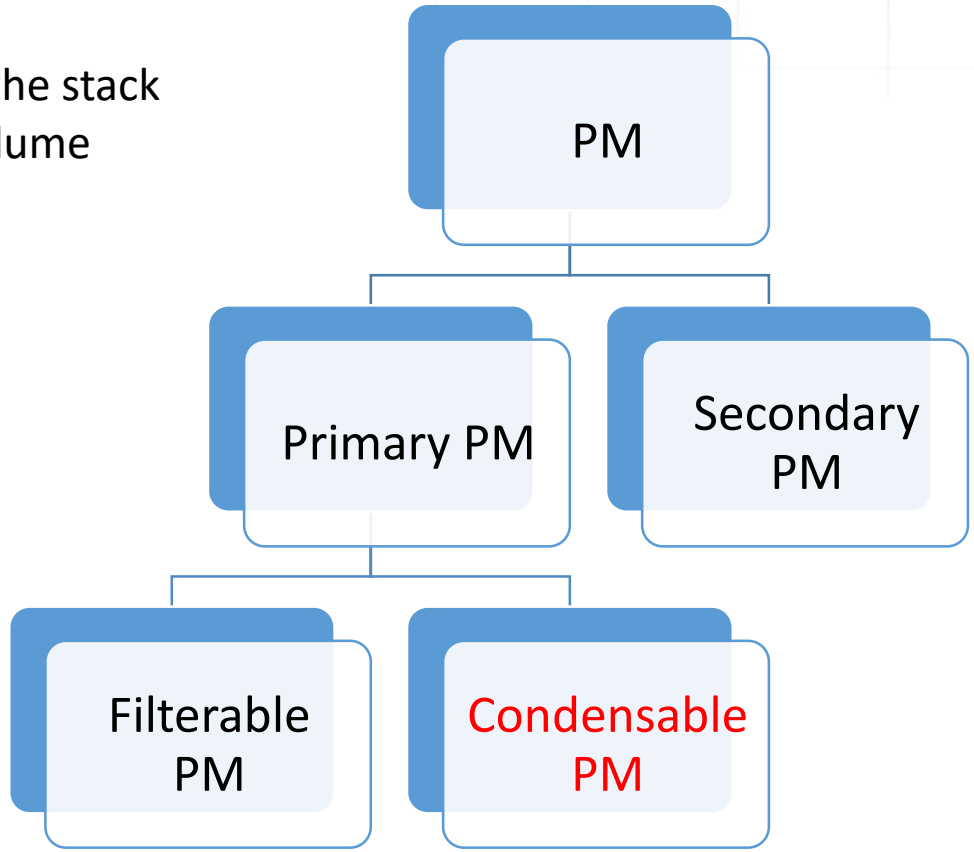
- Exists as a vapor in stack plume at stack exit conditions
- Changes to liquid aerosols and fine solids immediately after exiting the stack and cooled by dilution with atmospheric air entrained in the stack plume
- Product of physical and chemical processes in stack plume

Secondary PM

- Formed in the atmosphere via slower chemical and photochemical reactions; farther from stack
- Precursors (NOx, SO_2, VOC, Ammonia)

Primary PM

- Sum of Filterable PM and Condensable PM
- Primary PM emissions are considered for Air Permitting but both Primary and Secondary PM are considered for NAAQS Compliance Demonstration



CPM is the most significant mass in Total PM for gas combustion (70% - 75%)

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CPM Formation During Dilution of Stack Plume

Physical Processes:

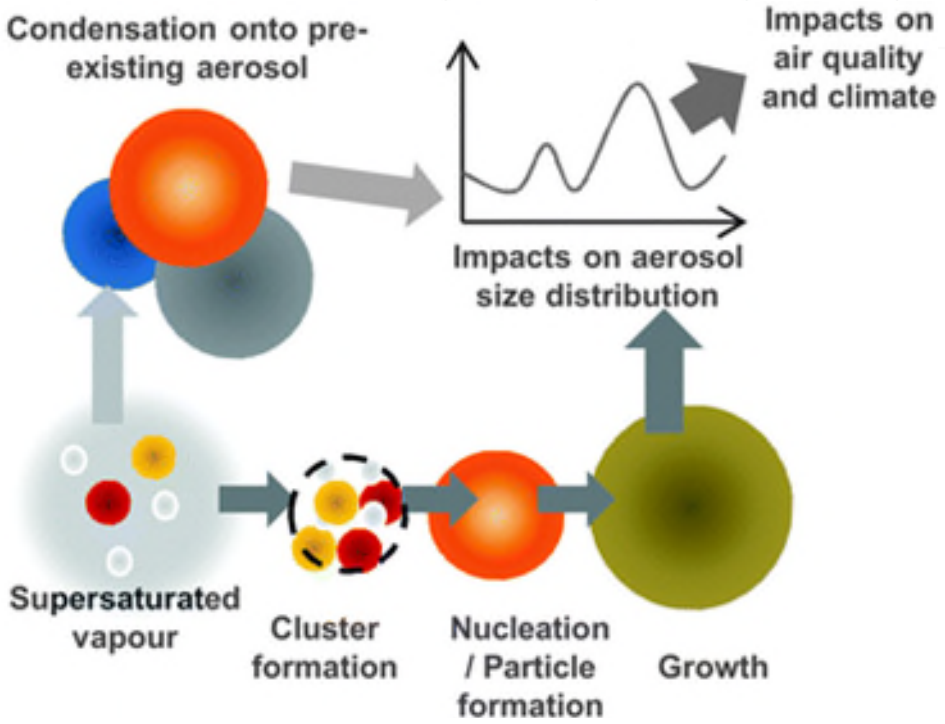
- Direct gas to particle formation (nucleation)
- Condensation on new and existing fine particle in gas stream (organics)

Chemical Process:

- Fast gas-liquid and gas-gas reactions(e.g., acids and ammonia)

CPM Precursors:

- Sulfuric acid, Nitric acid, Ammonia, and SVOCs in exhaust gas stream



Source: Chemical Society Reviews, Issue 15, 2012

CPM Speciation in Gas Combustion Exhaust

- Varies widely based on process and fuel type
- Constituents in fuels contributing to CPM
  - Sulfur content
  - Heavy organics (C6+)
- Typical CPM species in gas fired combustion exhaust
  - Ammonium salts (sulfates, nitrates, chlorides)
  - Organic aerosols (alkanes, PICs, SVOCs)
  - Sulfuric acid and nitric acid aerosols

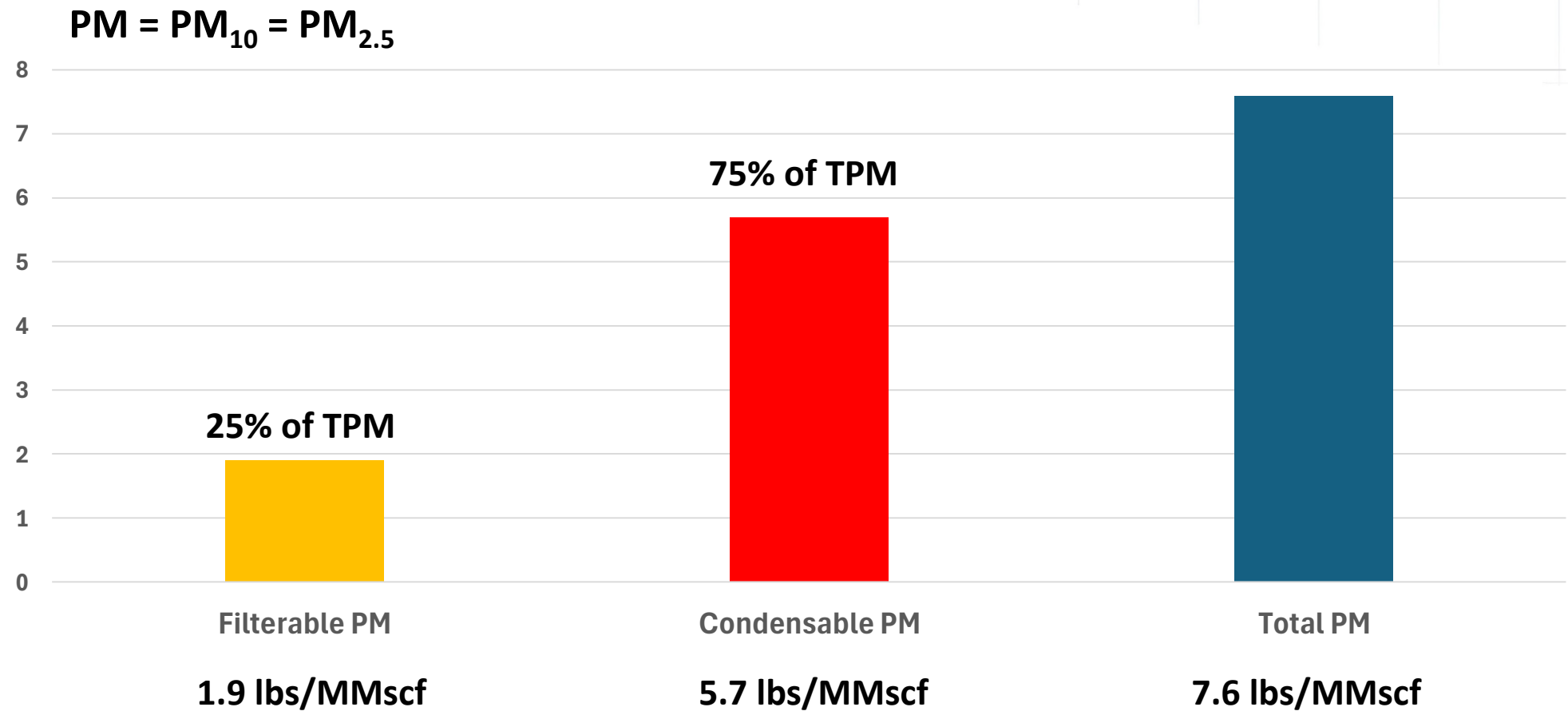
CPM Emission Factor (EF) for Gas Combustion

Current Status

CPM Emission Factor (EF) Basis

- USEPA AP-42 Chapter 1.4 (External Combustion – Natural Gas)
- Last updated in 1998 based on Tests in 1991-1994 timeframe
- 4 test results on Natural Gas fired combustion units were used to derive the CPM EF with Standard deviation (SD) of 119%
- CPM Emission Factor quality rating is D, which means:
  - *Below Average*. Factor is developed from test data from a small number of facilities, and there may be reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source population
- The current CPM EF do not reflect improvements in combustion technology and large variety of combustion unit designs and fuels

Current AP-42 PM Emission Factors
Gas Fired External Combustion Units



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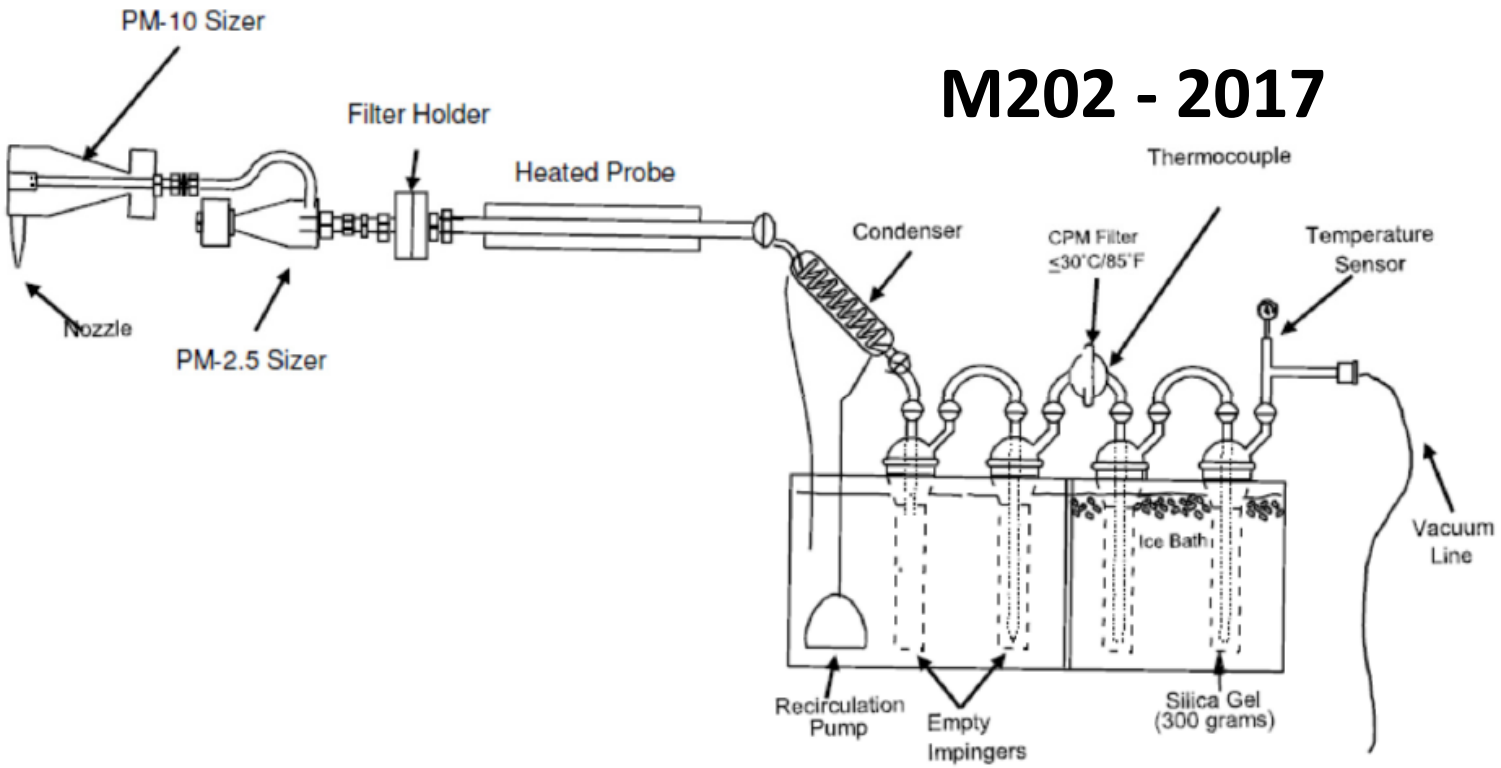
CPM Field Measurement



M202 - 2017

Method 202 (1991) – bubbled sample through water in iced impingers to rapidly cool the sample without dilution

Revised in 2010 and again in 2017 (current) – dry impinger method

Source: USEPA

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Method 202 Issues

- Method does not replicate the CPM formation in the atmosphere - dilution with entrained atmospheric air

- Known Biases increase EF
  - Condensation of water in impinger - aqueous chemistry between SO_2 and ammonia
  - Oversaturation of organic due to colder sampling temperatures

- Most recent version (2017) reduced, but did not eliminate these biases

- USEPA issued a memo in November 2024, to account for ammonium sulfate bias

AP-42 EFs are still based on 1991 Method 202 tests

Summary of Issues with AP-42 CPM EFs

- Few sample tests with large standard deviation
- Older test units - Do not reflect current combustion unit designs and fuels
- Emission factors have poor quality rating
- Test method (M202) have known bias and does not replicate CPM formation in the atmosphere
- Result is *highly conservative* CPM EFs for gas fired units

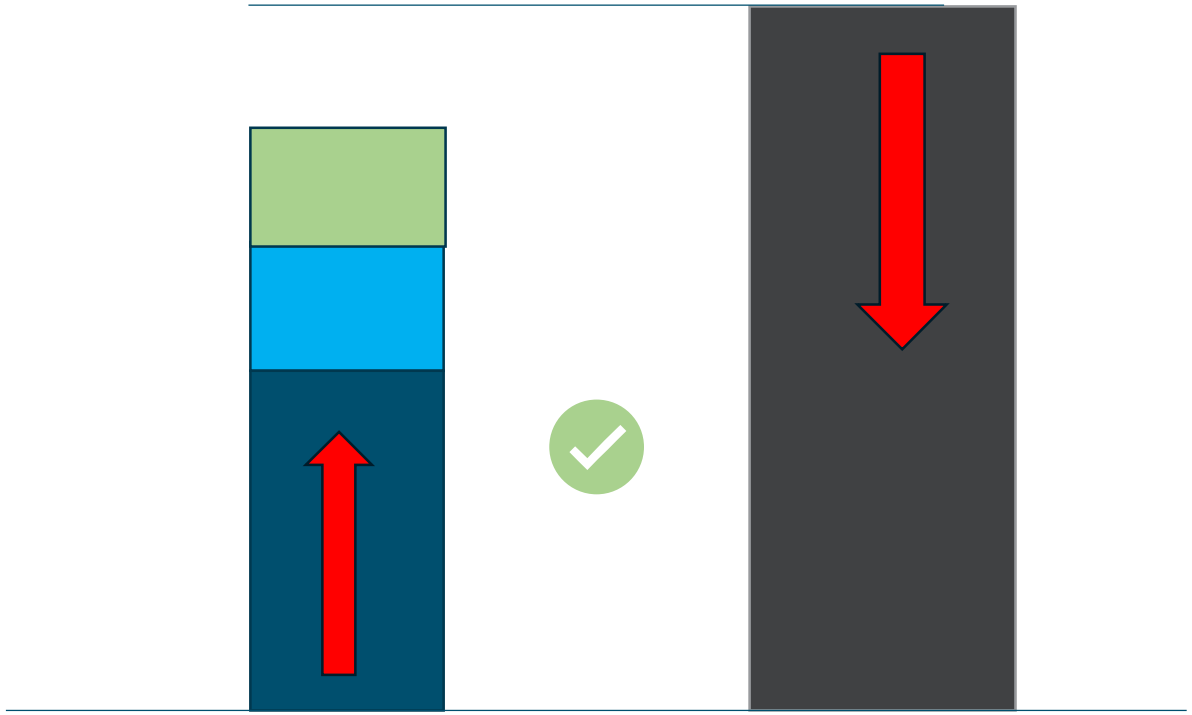
Current CPM Emission Factor

Impacts on Air Permitting

$PM_{2.5}$ NSR Air Permitting

- CPM is generally considered as <1 microns and therefore all CPM is part of $PM_{2.5}$
- NSR "Major Modification" threshold for $PM_{2.5}$ is 10 tpy
- The highly conservative CPM EF results in many unnecessary permitting and regulatory planning complications
  - Sources and projects unnecessarily trigger major source status or major modification adding significant burden on permit applicants (NAAQS/Offsets)
  - Regulatory agencies must evaluate and impose unnecessary stringent controls as part of SIP in Nonattainment areas

Annual $PM_{2.5}$ NAAQS Compliance Demonstration Issue



Project Impact

Other On-site and Offsite Nearby Sources

Background

NAAQS

Projects with impact > De Minimis (SIL)

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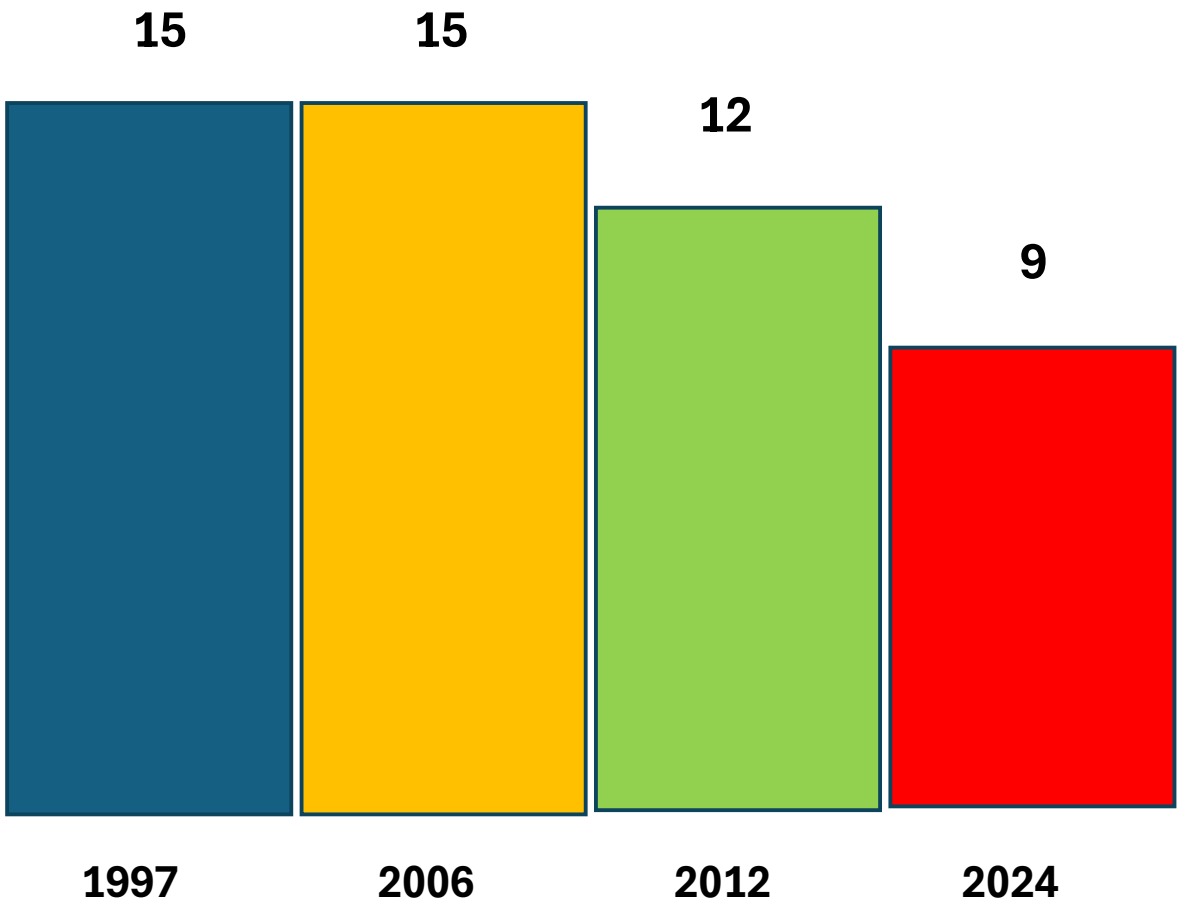
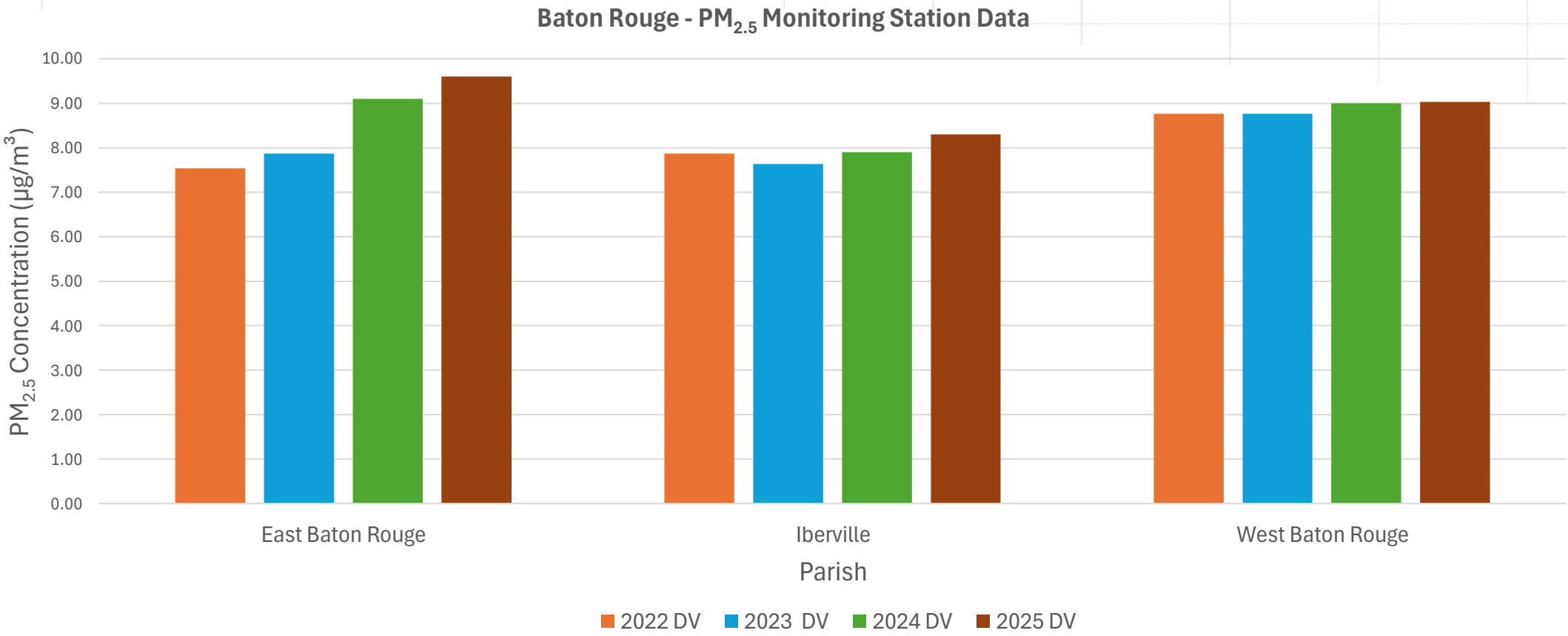


Annual $PM_{2.5}$ NAAQS Reduced over the years (ug/m3)

Annual $PM_{2.5}$ NAAQS Compliance Demonstration Issue



For Projects in areas with $PM_{2.5}$ annual background DV of 9 or higher, only option to demonstrate annual $PM_{2.5}$ NAAQS compliance is to limit project impact below SIL of 0.13 ug/m3

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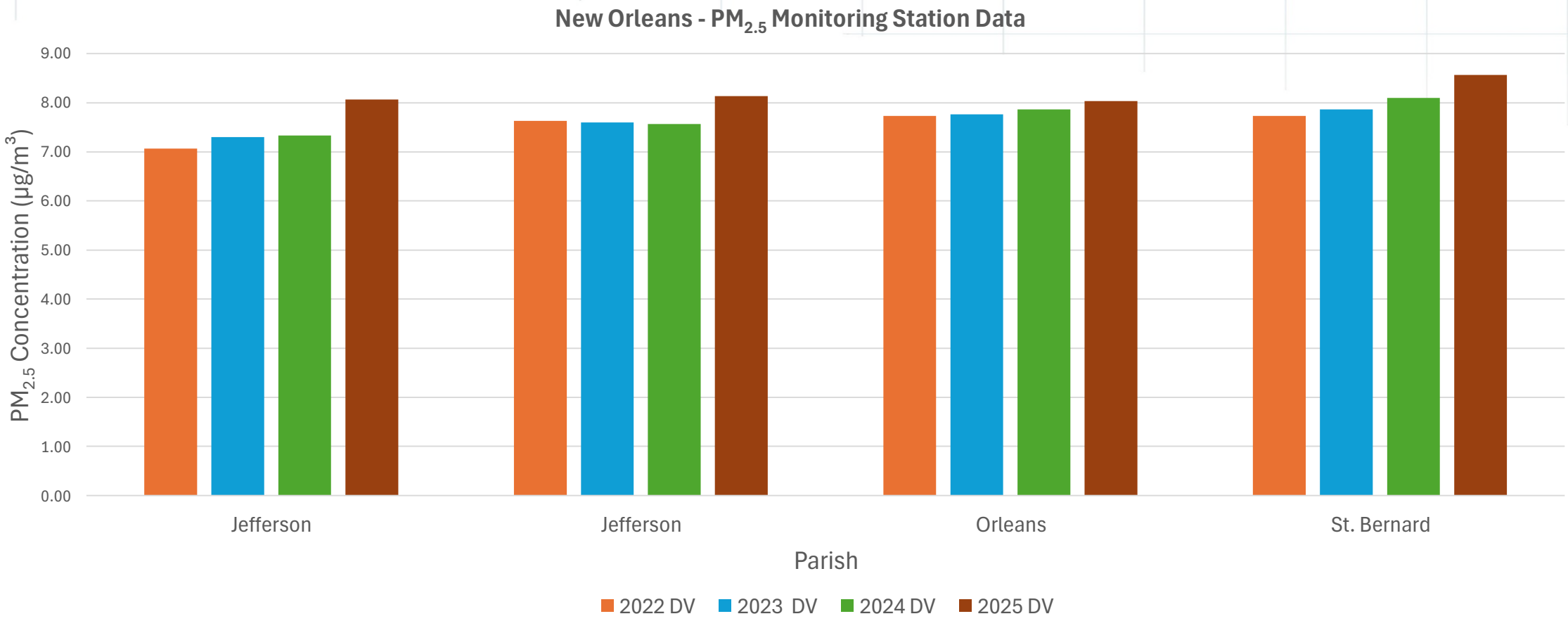

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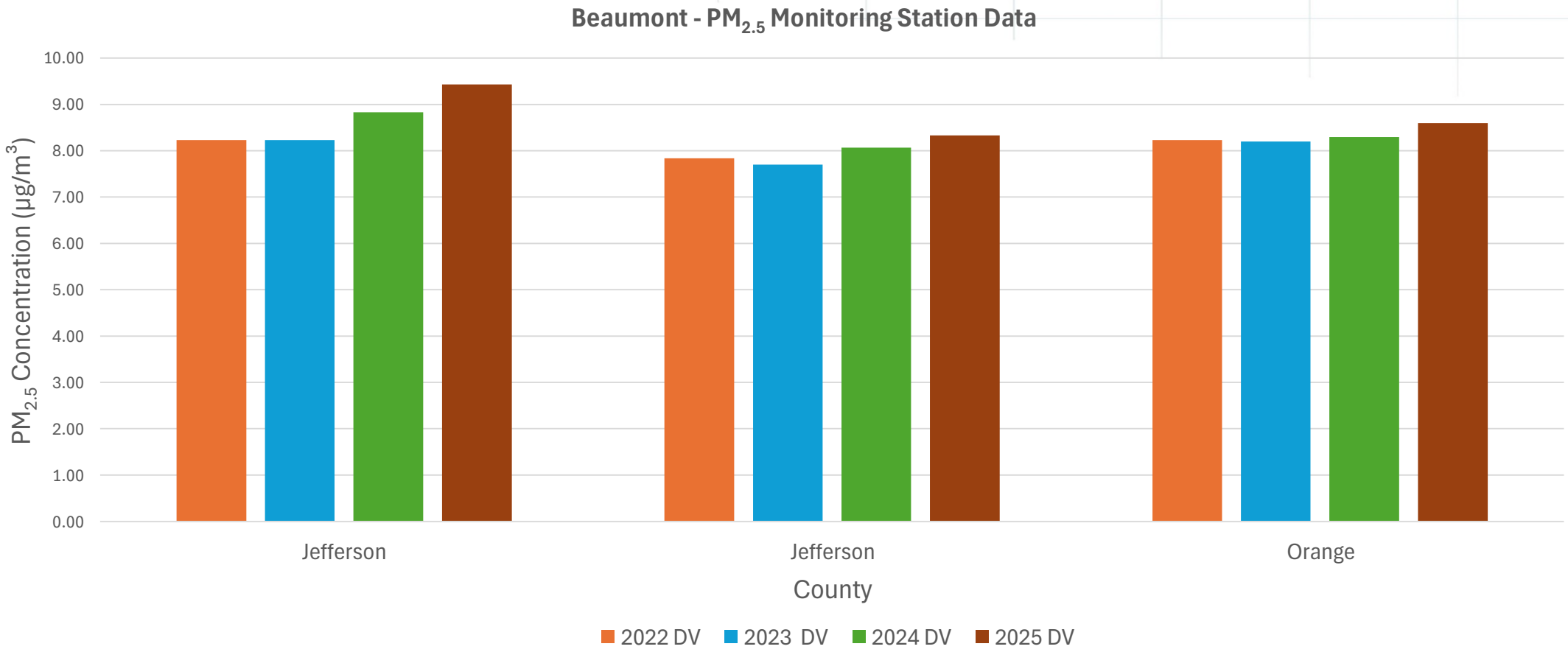

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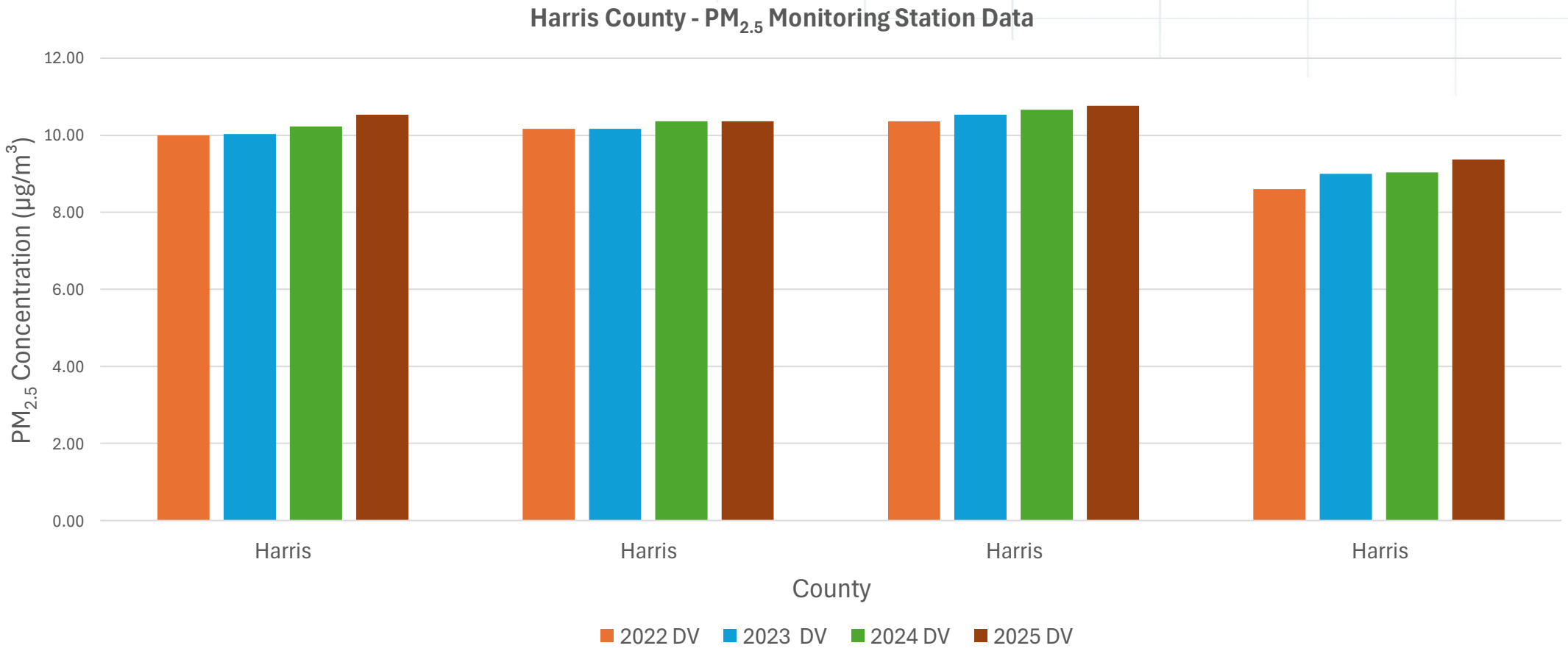

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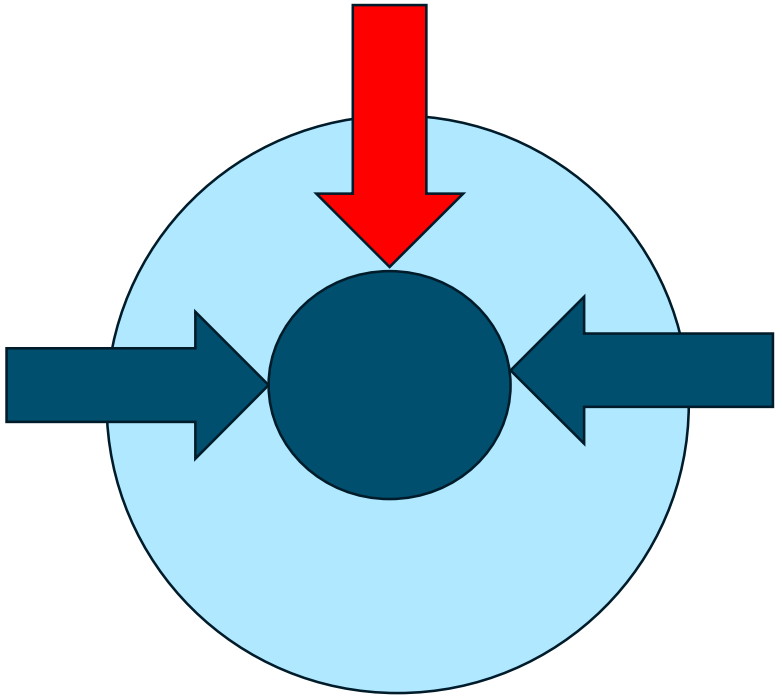
The Squeeze on Allowable Project $PM_{2.5}$ Emissions for Demonstrating Compliance with Annual NAAQS

Highly Conservative CPM EF

Lower Annual $PM_{2.5}$ SIL & NAAQS



Higher Background Concentrations

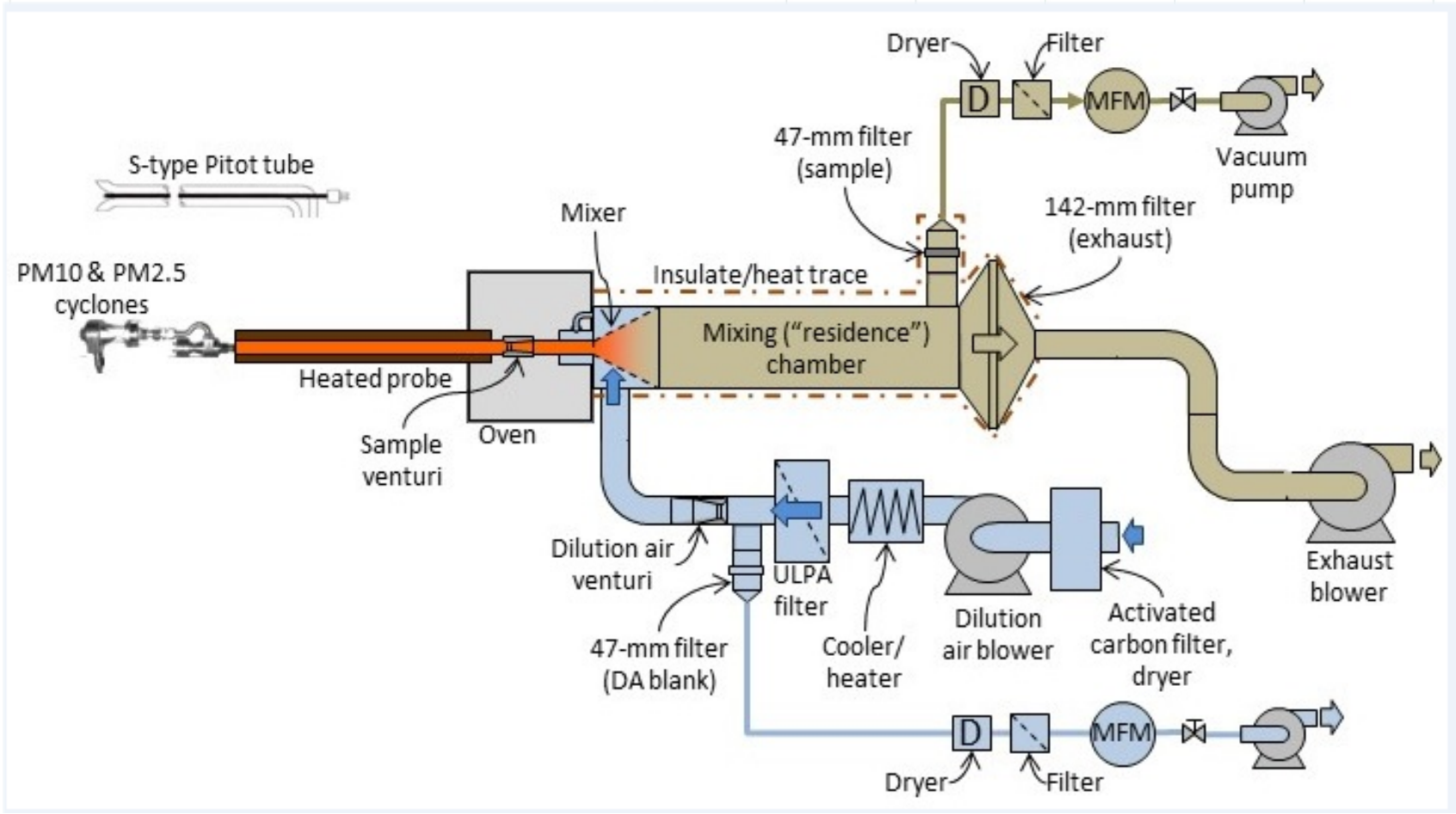
Only the CPM EF can be refined by industry and regulating agencies

Alternative CPM Emission Factor

Dilution Sampling Method

- Purpose is to eliminate biases in Method 202 and replicate the CPM formation in stack exhaust as it is diluted in atmosphere
- Several versions have been tried in field studies since early 2000
- Similar methodology is currently used in mobile source sampling
- USEPA published two test methods based on dilution sampling
  - Conditional Test Method (CTM-39) in 2004
  - Other Test Method (OTM-37) in 2017 = building on CTM-39
- Both methods have not yet been approved for regulatory applications

Dilution Sampling Method (USEPA OTM-37)



Dilution Sampling Method measures Total PM (Filterable and Condensable PM) together

Source: USEPA

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Dilution Sampling Method - Published Field Studies

Year	Reference	Units Tested	# of Test Data (Boilers/Heaters)
2001	API Publications 4703, 4704 and 4712	Boilers/Process Heaters	9
2004	NYSERDA/GRI/API/NETL	Boilers/Process Heaters/GTs	10
2021	Concawe 1 (EU)	Process Heater (RFG)	3
2022/2023	Concawe 2 (EU)	Process Heater (RFG)	18
		Total	**40**

The field tests utilized various types of dilution sampling methods

For comparison, current AP-42 CPM EF is based on 4 tests

Dilution Sampling Method
Statistics of Published Field Studies

Boilers
(% of AP-42 EF)

Average	5%
Std Dev	3%
95% CI	2.03%
Min	0.2%
Max	8.5%

Process Heaters
(% of AP-42 EF)

Average	4%
Std Dev	8%
95% CI	4.87%
Min	0.1%
Max	26.5%*

* Potentially an outlier

For Comparison - Current AP-42 CPM EF Standard Deviation is 119%

Dilution Air Method – USEPA Concerns

- Increasing dilution air may result in artificially lower CPM
- Sampling train surface deposition may affect the CPM results
- Unsure about impacts of organics on CPM formation
- Not fully validated through precision and bias testing. Concerns about repeatability and actionability of the method results
- Unavailability of useful field data which includes field comparison of OTM 37 and M202 coupled with precursor data

Summary

Summary

- Current AP-42 CPM EF for gas fired combustion units are based on old test data that does not reflect currently diverse and efficient combustion units - highly conservative EF
- Numerous field data with dilution sampling methods simulating CPM formation in the atmosphere have shown order of magnitude lower CPM EF than AP-42 EF
- Industry may want to undertake Dilution Sampling field studies (e.g., OTM-37) to address USEPA's concerns
- Agencies be open to accepting Dilution Sampling field test data and revise the AP-42 EFs based on results

Thanks for your Time

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