

# ECMA's ECT - 2025

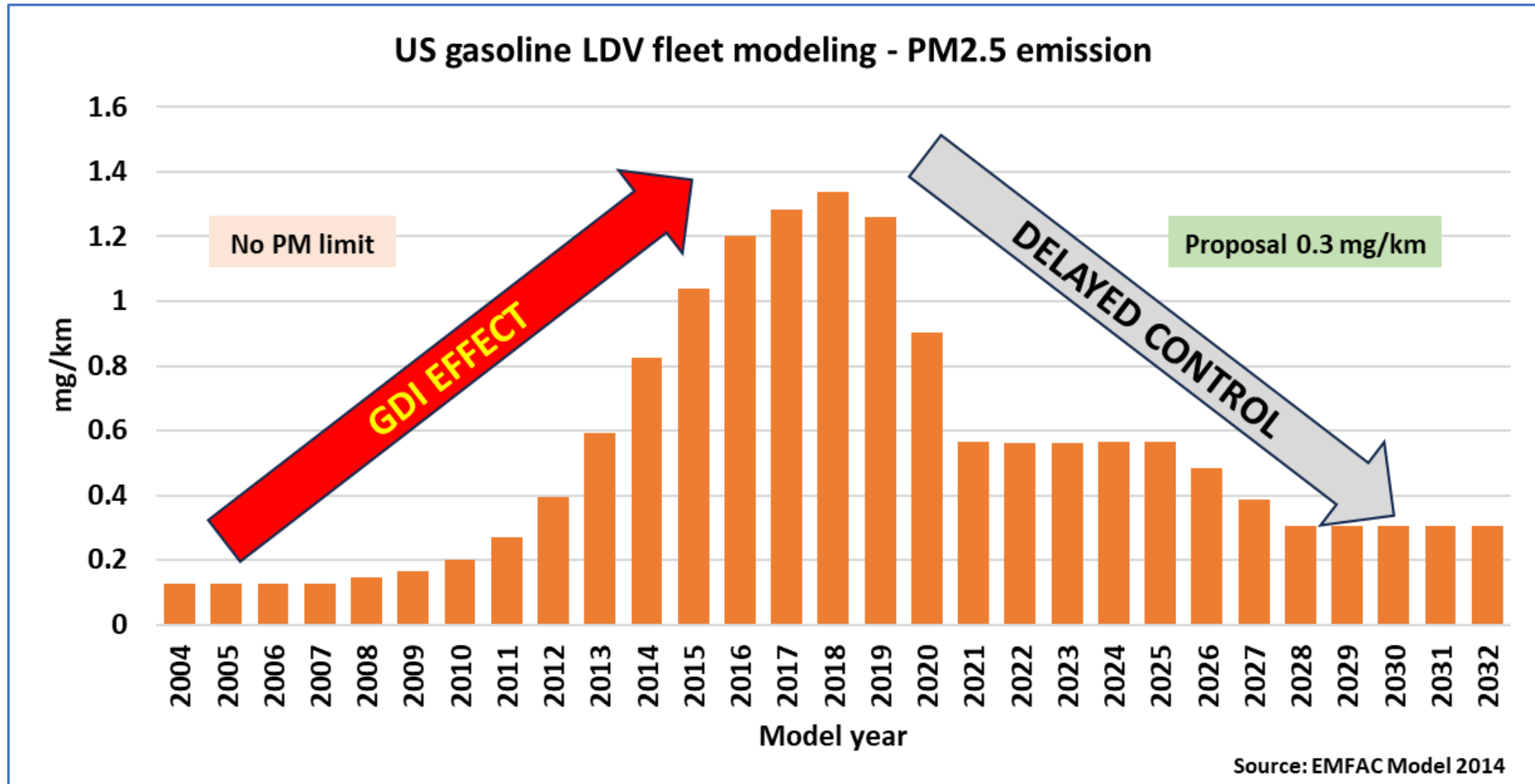
## 16th International Conference & Exposition

### Comparison of Particulate Emissions from Different Categories of Diesel and Otto Engines and Vehicles

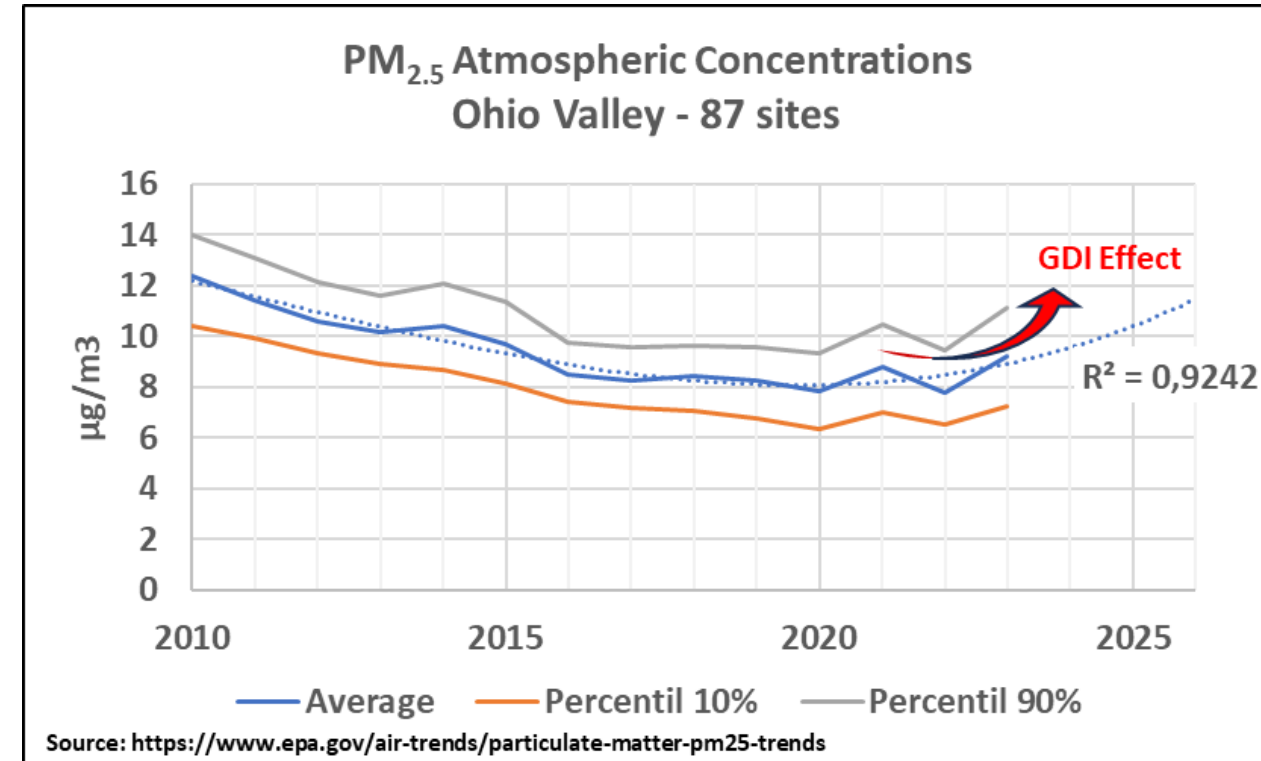
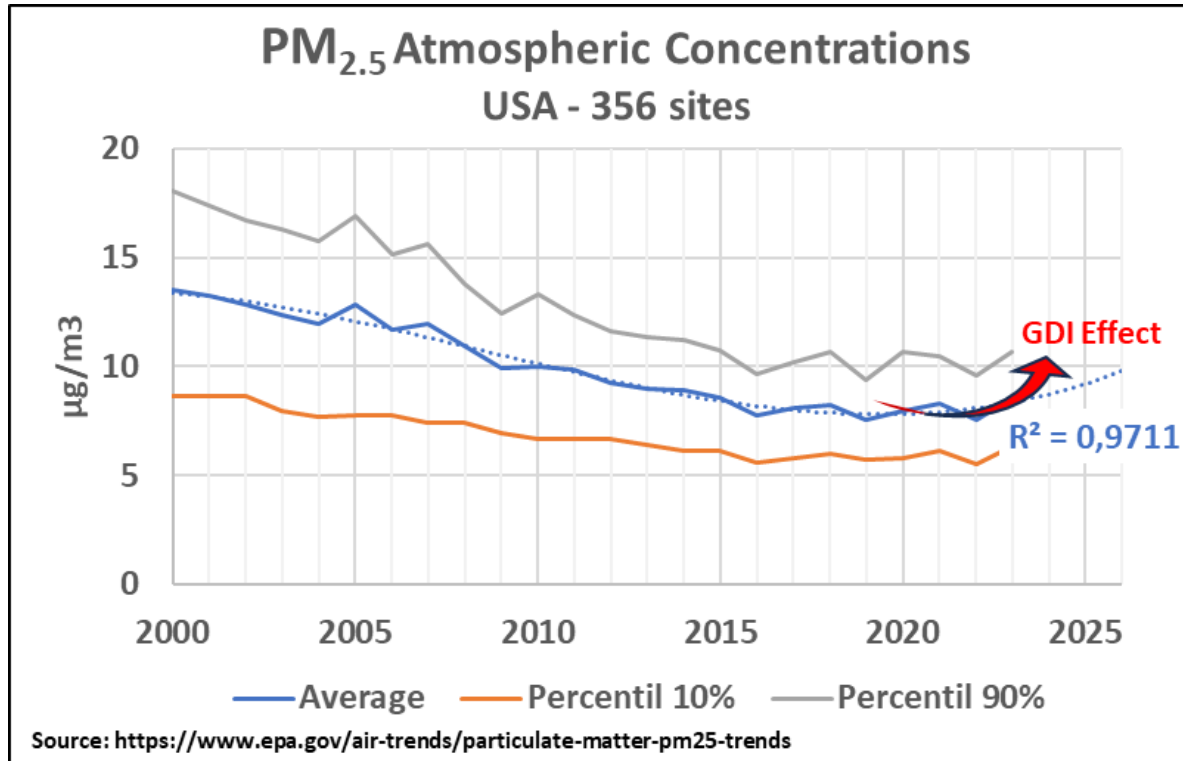
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7th and 8th October 2025

## Observing GDI market penetration in USA...



# Annual Atmospheric Averages of PM<sub>2.5</sub> - USA



| HDV Phase    | PM mg/kWh | Notes                                                            |
|--------------|-----------|------------------------------------------------------------------|
| Pre PROCONVE | 1500      | Old typical data, converted to equivalent values in the ETC test |
| P3 - 1996    | 1100      |                                                                  |
| P4 - 2000    | 250       |                                                                  |
| P5 - 2005    | 160       | Limit - Introduced S500 diesel oil                               |
| P6 - 2009    | 30        | Phase canceled due to unavailability of S50 diesel oil           |
| P7 - 2012    | 30        | Limit - Introduced S10 diesel oil                                |
| P8 - 2023    | 10        | Mass limit in addition to the limit of                           |

| PM Emission std (mg/km) - Light-duty Vehicles |      |           |             |        |
|-----------------------------------------------|------|-----------|-------------|--------|
| PROCONVE phase                                | Year | Passenger | Commercials |        |
|                                               |      | Cars      | Otto        | Diesel |
| L7 /L8 - individual                           | 2022 | 6         | 6           | 20     |
| L8 - corporate                                | 2025 | 4         | 6           |        |
|                                               | 2027 | 4         | 6           |        |
|                                               | 2029 | 3         | 4           |        |
|                                               | 2031 | 3         | 4           |        |

| PM Emission Averages - mg/km |                    |         |               |                     |               |         |               |
|------------------------------|--------------------|---------|---------------|---------------------|---------------|---------|---------------|
| Calendar Year                | Passenger Vehicles |         |               | Commercial Vehicles |               |         |               |
|                              | Flex -Ethanol      | Gasohol | Flex -Gasohol | Diesel              | Flex -Ethanol | Gasohol | Flex -Gasohol |
| 1997 a 2011                  | 1,1                | 1,1     | 1,1           | 65                  | 1,1           | 1,1     | 1,1           |
| 2011 a 2021                  | 1,1                | 1,1     | 1,1           | 13,6                | 1,1           | 1,1     | 1,1           |
| 2022 (L7)                    | 1,6                | 1,3     | 3,0           | 2,0                 | 1,6           | 2,3     | 3,0           |
| 2023                         | 2,4                | 1,3     | 2,9           | 1,1                 | 1,0           | 1,7     | 3,5           |
| 2024                         | 1,7                | 1,2     | 2,4           | 0,7                 | 1,0           | 1,8     | 3,5           |
| 2022-24 Ave.                 | 1,9                | 1,3     | 2,8           | 1,2                 | 1,2           | 1,9     | 3,3           |



# LDV x HDV: Certification Data Relationship

**CERTIFICATION – Dynamometer and RDE:**

EMISSION: g/km or g/kWh

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FUEL CONSUMPTION in the SAME TEST:  
L/km or g/kWh

**RS Measurements**

CO/CO<sub>2</sub>  
HC/CO<sub>2</sub>  
NO<sub>x</sub>/CO<sub>2</sub>  
MP/CO<sub>2</sub>

Data in ppm

Carbon Balance:  
g\_pollutant/Mo  
l C or g/kg  
Carbon

Correlation Established  
in g/kg\_fuel

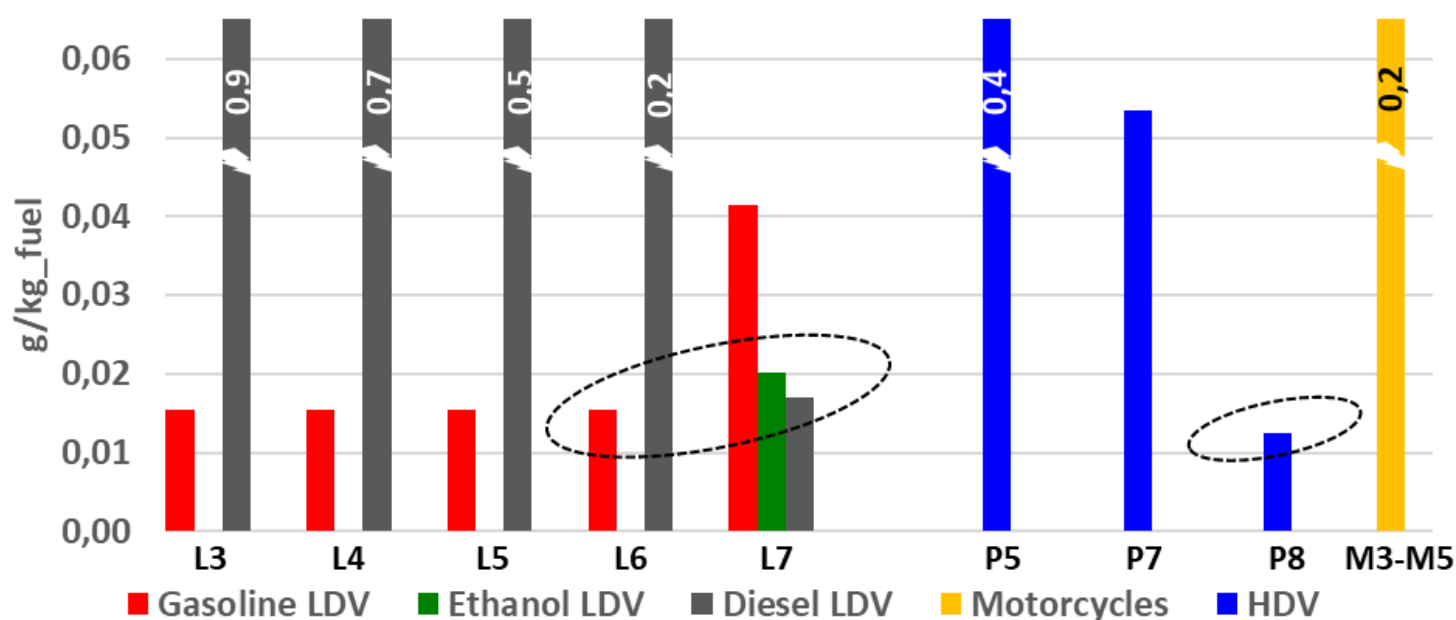
REFERENCE  
VALUES

Vehicle

Emission in  
g/kg Fuel  
(or g/kg  
Carbon)

g/kg

Certified PM Emissions Averages



## Important Findings for PM control:

- Otto LDV had the lowest PM emissions up to phase L6
- GDI from gasoline and flex-fuel engines increased PM emissions by more than 100%
- Fueling GDI with ethanol appears to be compatible with previous phases levels
- diesel light and heavy-duty engines have been drastically reduced in stages L7 and P8 (95% to 99%), being compatible with those traditional gasoline MPFI

## Preliminary Conclusions:

- It is possible to reduce GDI PM emissions to former levels immediately.
- The use of ethanol seems to be a possibility for mitigating this problem.
- Brazil already has technological solutions and aftertreatment systems for reducing PM emissions from light duty diesel engines to the required levels, which can also be used for Otto GDI engines.

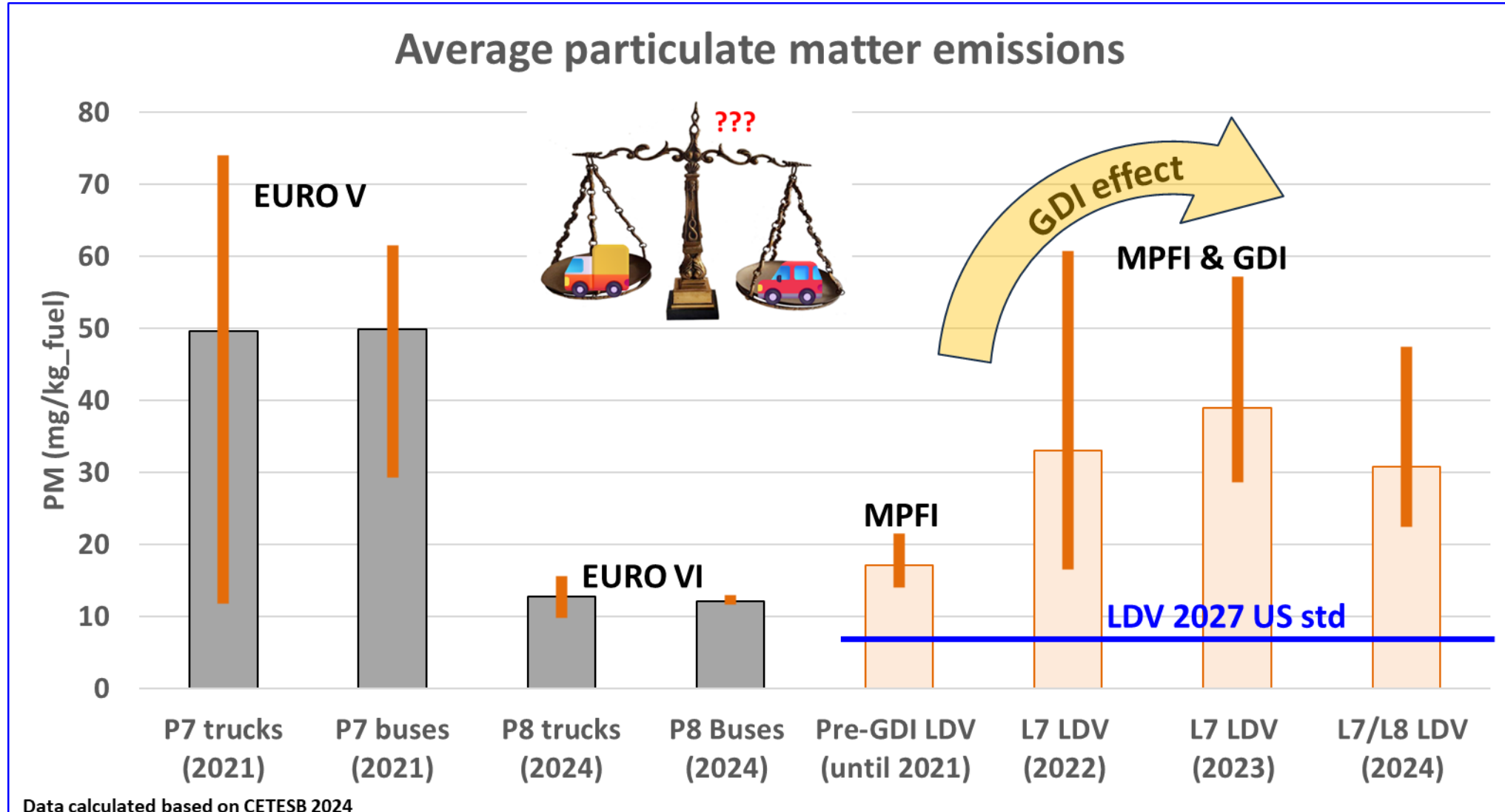
Motorcycles technologies still allow high PM emissions, at levels almost four times higher than those of HDE of the P7 phase.

# Fuel Sales by Brazilian Region in 2024

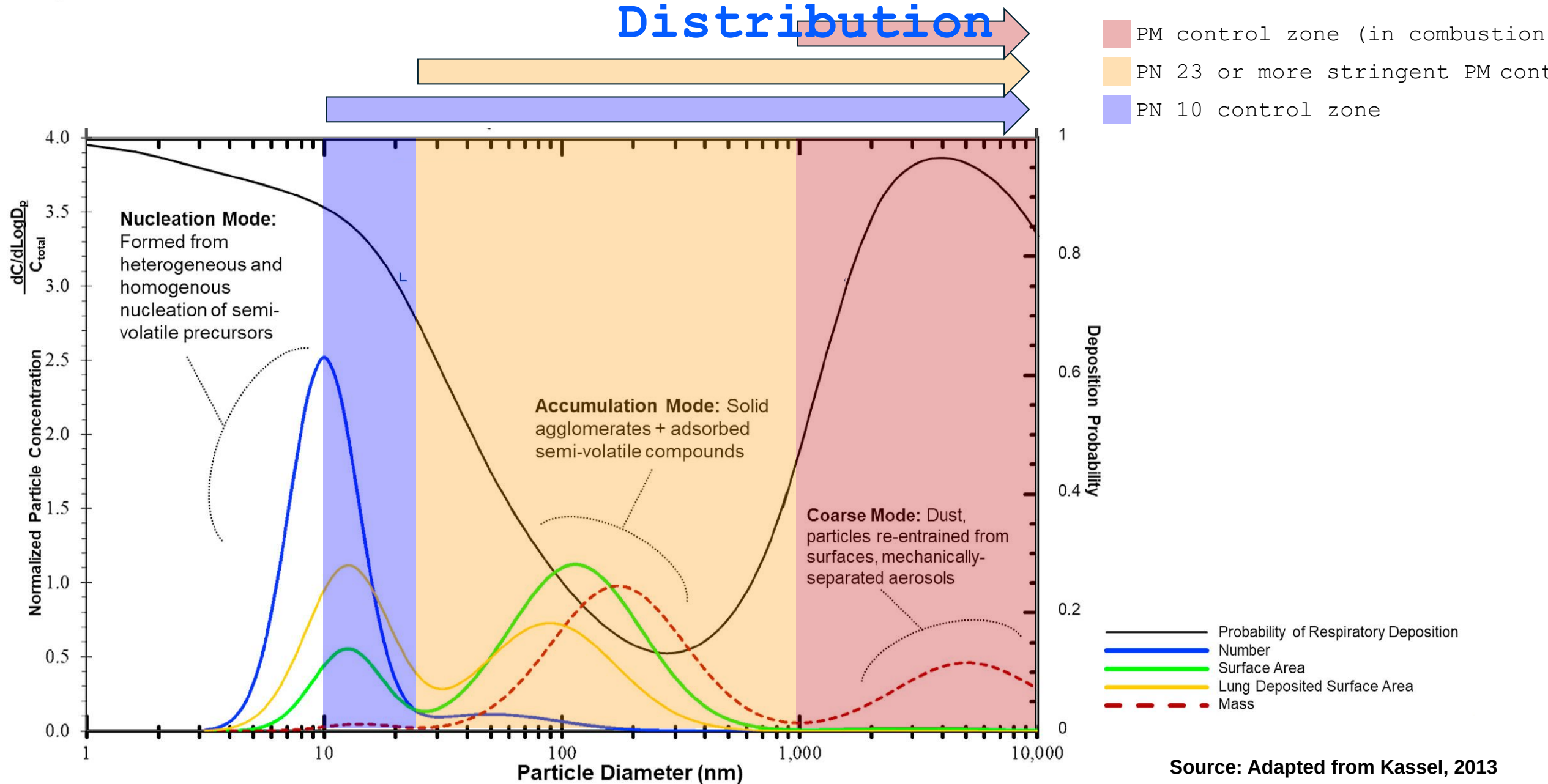
| Base year: 2024     | HYDRATED ETHANOL | E27 GASOHOL | DIESEL OIL |
|---------------------|------------------|-------------|------------|
| <b>BRAZIL</b>       | <b>16%</b>       | <b>33%</b>  | <b>50%</b> |
| SÃO PAULO STATE     | 31%              | 28%         | 41%        |
| SOUTHEAST REGION    | 25%              | 30%         | 46%        |
| NORTHEAST REGION    | 8%               | 44%         | 49%        |
| SOUTH REGION        | 7%               | 40%         | 53%        |
| CENTRAL-WEST REGION | 21%              | 22%         | 57%        |
| NORTH REGION        | 4%               | 33%         | 63%        |

Source: based on ANP data (National Agency for Petroleum, Natural Gas and Biofuels)

# Heavy Duty x Light Duty PM Emission



# Exhaust Emission Particles Size Distribution



Source: Adapted from Kassel, 2013

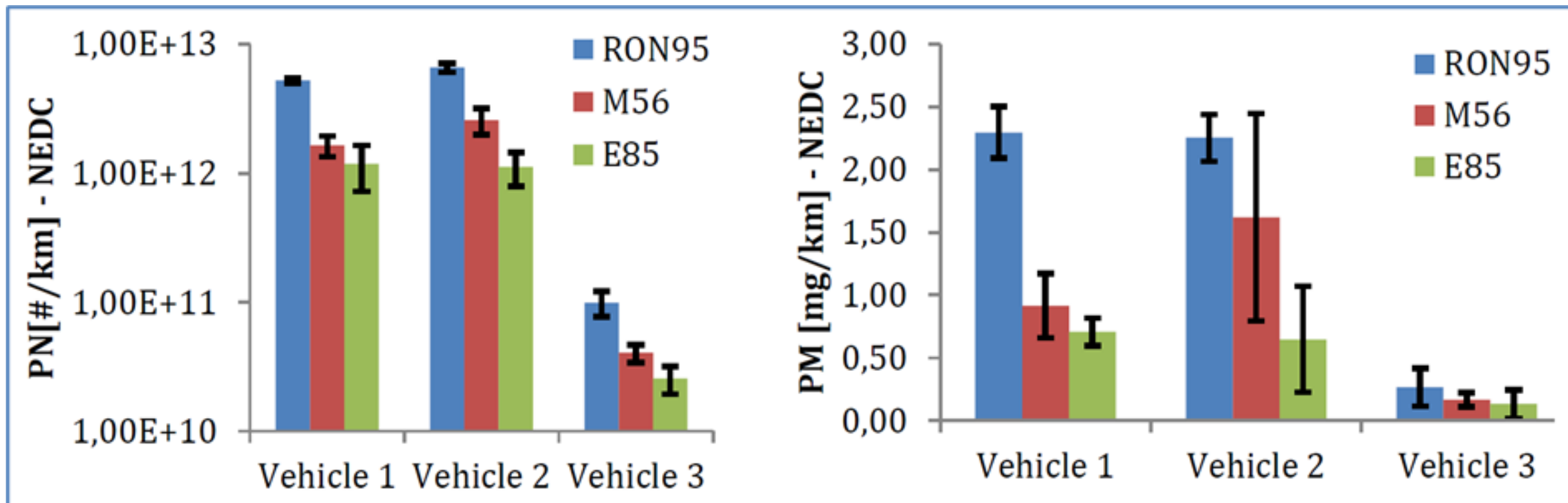
# Ethanol's Influence on PM and PN

E20 reduces PM by

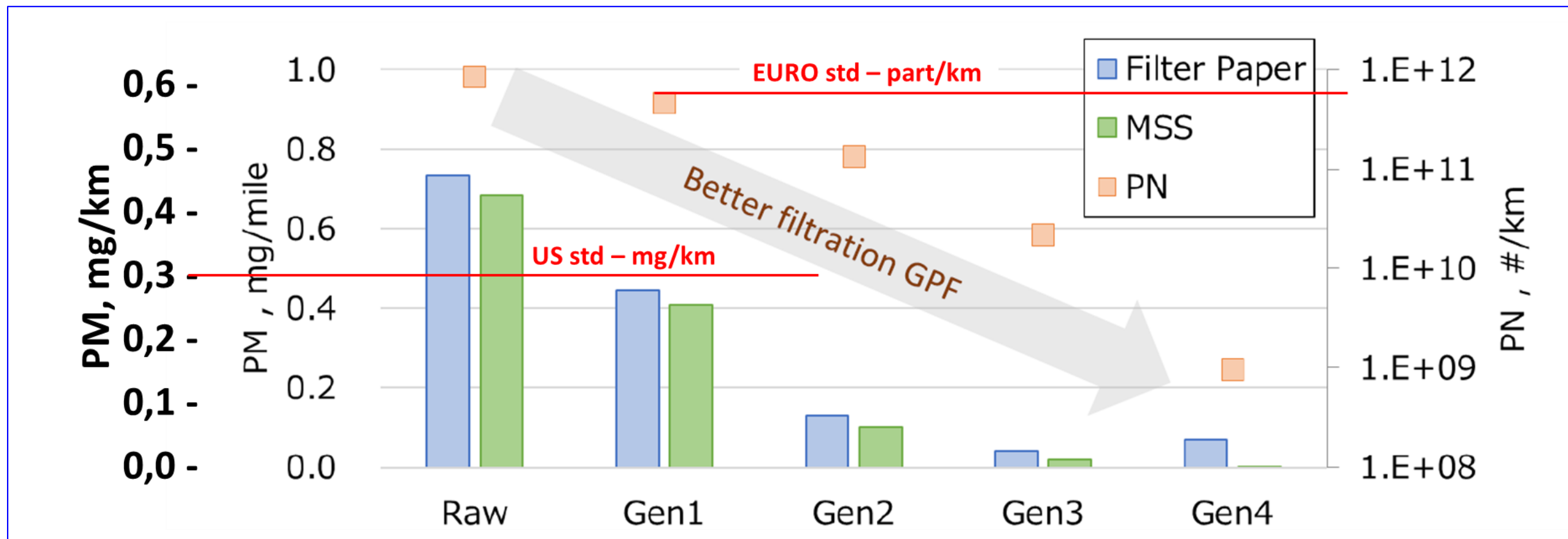
~20%

E30 reduces PM up to

45%



# Ceramic Filters Evolution from 1<sup>st</sup> to 4<sup>th</sup> Generation



# Balancing PM Emissions from Vehicles and Engines

| PROCONVE            | Category               | Particulate Matter Emissions |                                  |                            |
|---------------------|------------------------|------------------------------|----------------------------------|----------------------------|
|                     |                        | Standards                    |                                  | mg/kg <sub>fuel</sub>      |
| Phase P8            | trucks and buses       | 10mg/kWh                     | $6 \times 10^{11}$ part/kWh WHTC | 10 a 16<br>(2024 averages) |
| Phase L8            | cars and pickup trucks | 4mg/km                       | ---                              | 29 a 57<br>(2024 averages) |
| Phase L8 adjustment | cars and pickup trucks | 1mg/km                       | ---                              | 18 (2021 averages)         |
| New Phase L9        | cars and pickup trucks | 0.3mg/km                     | $6 \times 10^{11}$ part/km       | 06 (~ 1/3 of pre-GDI)      |

# Extension of PM Emission Analysis to HD Engines

Typical particulate matter emissions from machinery and generators

| PROCONVE                        | Category           | Particulate Matter Emissions |                             |                                                                       |
|---------------------------------|--------------------|------------------------------|-----------------------------|-----------------------------------------------------------------------|
|                                 |                    | Standards                    |                             | mg/kg <sub>fuel</sub>                                                 |
| Phase MAR I                     | non-road machinery | 200 to 600 mg/kWh            | ---                         | 900 to 2400 (average depending on machine type)                       |
| Phase MAR II (under discussion) | non-road machinery | 20 to 30 mg/kWh              | ---                         | 90 to 125 (standards)<br>50 (expected average - equivalent to P7)     |
| Current market (unregulated)    | generators         | ---                          | ---                         | 2200 to 4200 (estimated as Tier 1)                                    |
| New program (under discussion)  | generators         | 20mg/kWh                     | ---                         | 90 to 125 (standards)<br>50 (average - equivalent to P7/MAR II)       |
| New program (under discussion)  | special generators | 10mg/kWh                     | 6x10 <sup>11</sup> part/kWh | 10 to 16 (equivalent to average P8, for recharging electric vehicles) |

- a) **Route Correction: Jan. 1st, 2029** – change in BIN 30 and BIN 20 for light-duty passenger vehicles;
  - corporate PM emission std → 1 mg/km (mass) ;
  - measurement of typical  $PN_{10}$  values for MPFI and GDI.
- b) **PM emission reduction: Jan. 1st, 2031;**
  - PM (mass) standard of 0.3 mg/km;
  - $PN_{10}$  standard of  $6 \times 10^{11}$  particles/km.
- c) to extend this analysis to individual particulates results in current Brazilian LDVs;
  - **Measuring PM and PN** from GDI and MPFI vehicles, **using E30 gasohol**;
  - **Check the effectiveness of E100** fuel in reducing PM and PN.
- d) **Filtration technologies** associated with catalysts have to be addressed to provide better public health protection and helping to meet the Air Quality Standards;
- e) Harmonize particulate limits for **special generator sets**, whose power generation is also used to recharge electric vehicles.

# Thank you!

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