Physical & Chemical Characterization of Emissions from 2-Stroke Motorcycles

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Legislative Regulation of Scooter Emissions in EU

2-Stroke Mopeds 50 cm³

Driving Cycle	Regulated Compound	EURO-2 (2002) [g/km]
ECE47 (Hot Phase)	CO	1
	THC + NOx	1.2

Motorcycle < 150 cm³

Driving Cycle	Regulated Compound	EURO-3 (2006) [g/km]
ECE40 (Whole Cycle)	CO	2.0
	THC	0.8
	NOx	0.15

Diesel Passenger Car

Driving Cycle	Regulated Compound	EURO-5 (9/2009) [g/km]
UDC+EUDC (Whole Cycle)	CO	0.5
	THC + NOx	0.23
	NOx	0.18
	PM	0.005

Motorcycle > 150 cm³

Driving Cycle	Regulated Compound	EURO-3 (2006) [g/km]
ECE40+EUDC (Whole Cycle)	CO	2.0
	THC	0.3
	NOx	0.15

New Amendment for Directive 97/24/EC will come → EURO-3

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Main Objectives of Project at JRC:

- Investigation of Exhaust of different Mopeds complying with EURO-2
- Evaluation of Impact on Environment and Human Health
- Scientific Support on future legislative Regulations regarding…
  a) New Levels of already regulated Species
  b) Possibly additional regulated Constituents
- Evaluation of existing Test Protocol

Description of Project

Investigated Mopeds: 3 + 1 different types (50 cm^3)

- Carburetor: CA
- Direct Injection: DI
- Electronic Carburetion System ECS: CAec1 + CAec2

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ECS was rebuilt by Manufacturer after 1st Test Series, e.g.

a) Replacement of catalytic Converter
b) Replacement of semi-synthetic by fully-synthetic Oil
c) re-programming of ECS
d) Adjustment of Engine

Chemical & Physical Analysis:

- Total Hydrocarbon (THC), Carbon Monoxide (CO), Carbon Dioxide (CO_2), Nitrogen Oxides (NOx): on-line Sensors
- Particulate Matter (PM) for Total Mass: Differential weighing
- Carbonylic Compounds: HPLC
- Volatile Organic Compounds (VOC): GC-FID
- Polyaromatic Hydrocarbons (PAH) of PM: GC-MS

Calculation of…

- B[a]P Toxicity Equivalent (TEQ)
- Ozone Formation Potential (OFP)

Driving Cycles (3 replicates):

ECE47 (legislative driving cycle)

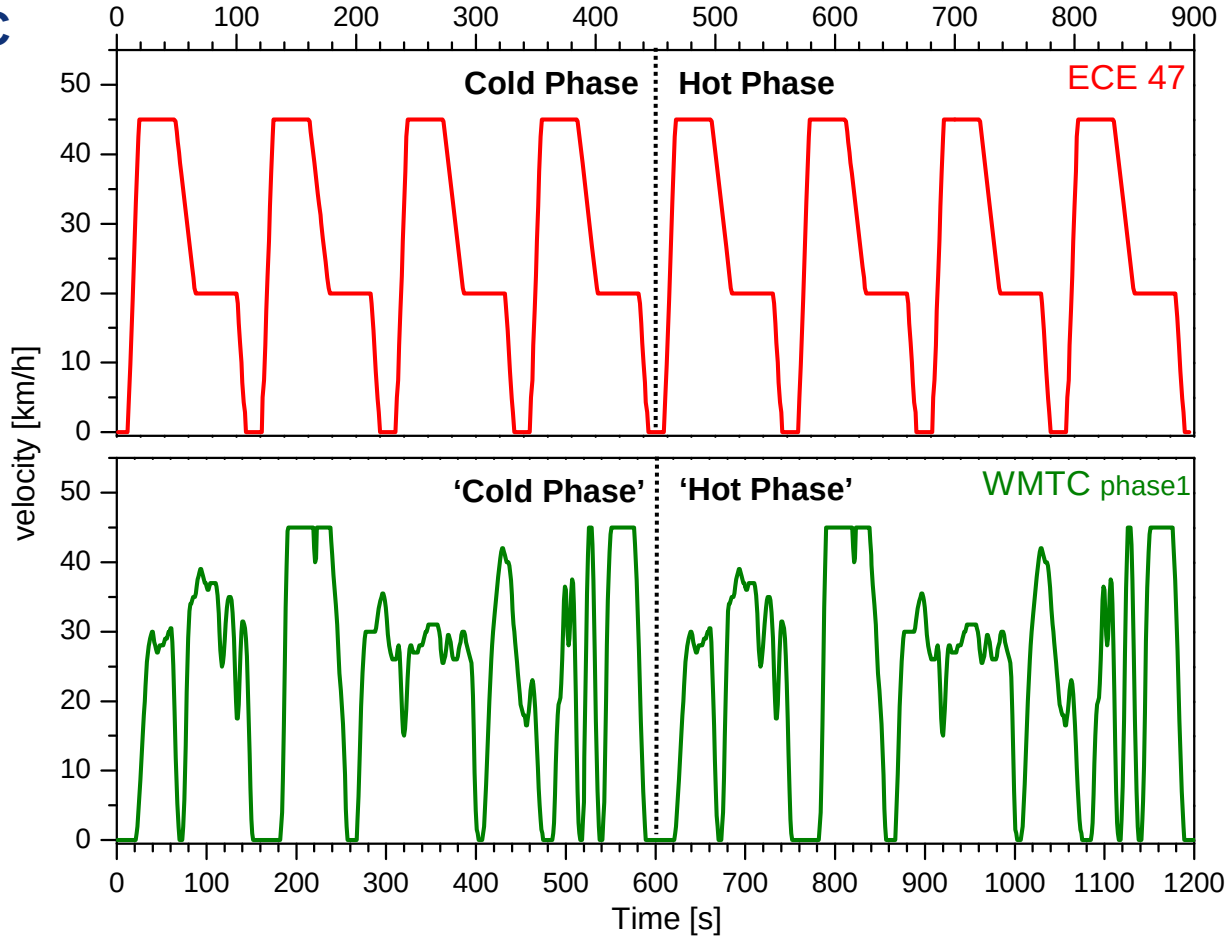
- Cold Phase
- Hot Phase

WMTC, Worldwide Motorcycle Test Cycle

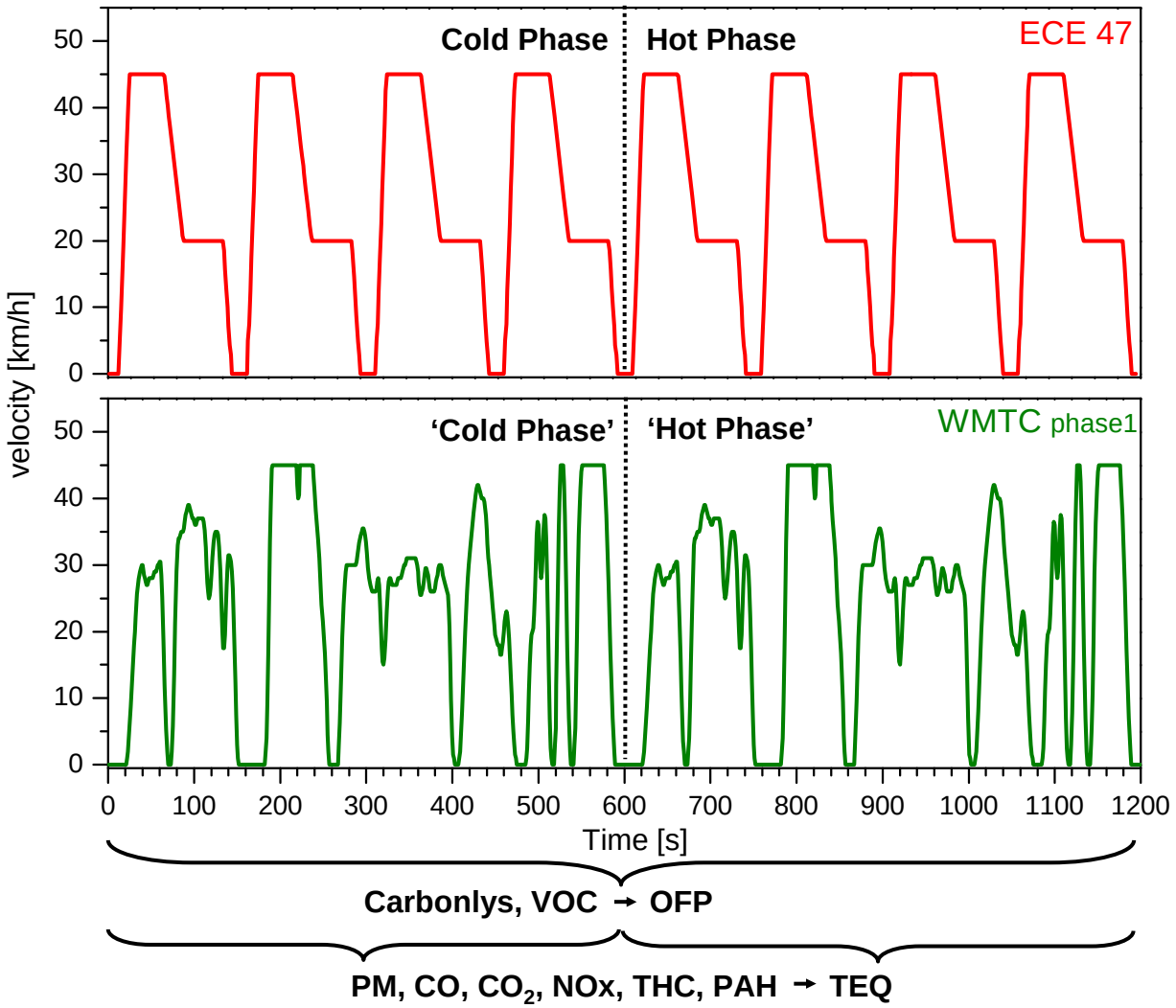
- 1st Phase only, twice in Succession
- Top Speed limited to 45 km/h
- ‘Cold Phase’
- ‘Hot Phase’

Description of Project

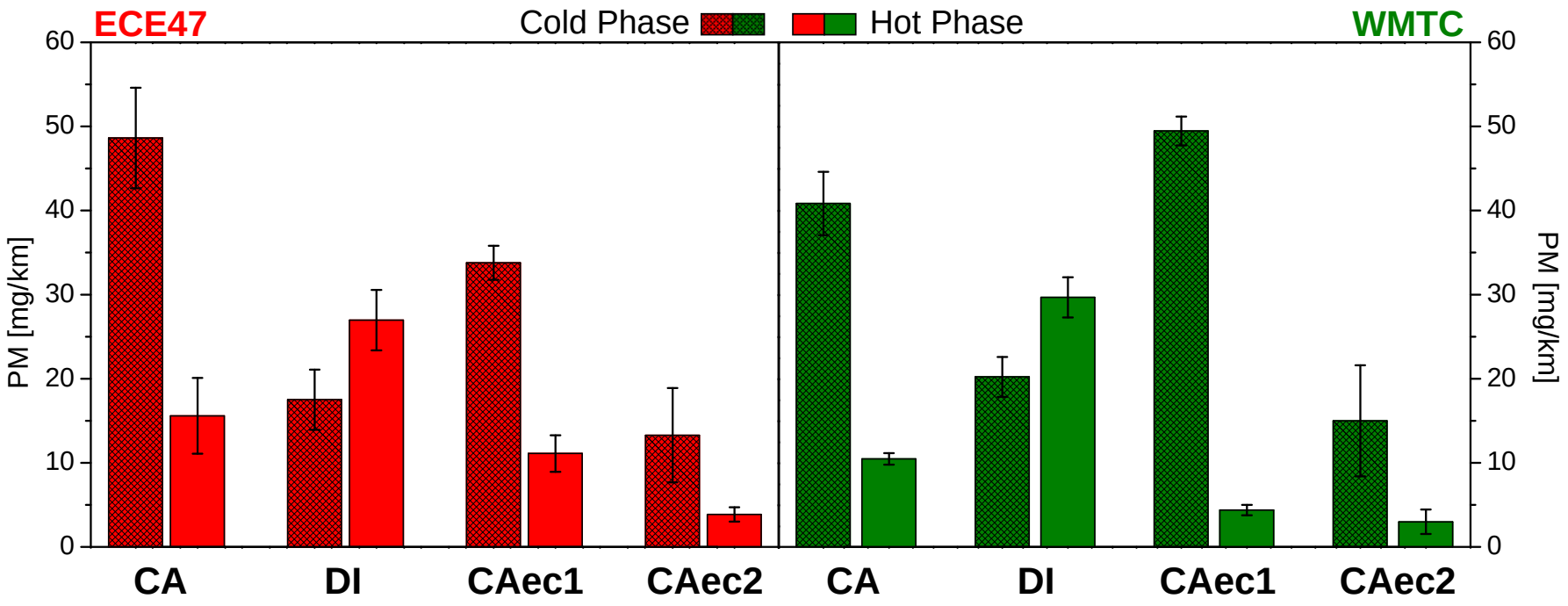
Driving Cycles:
ECE47 & WMTC



Driving Cycles & Chemical Analysis



Particulate Matter (PM):



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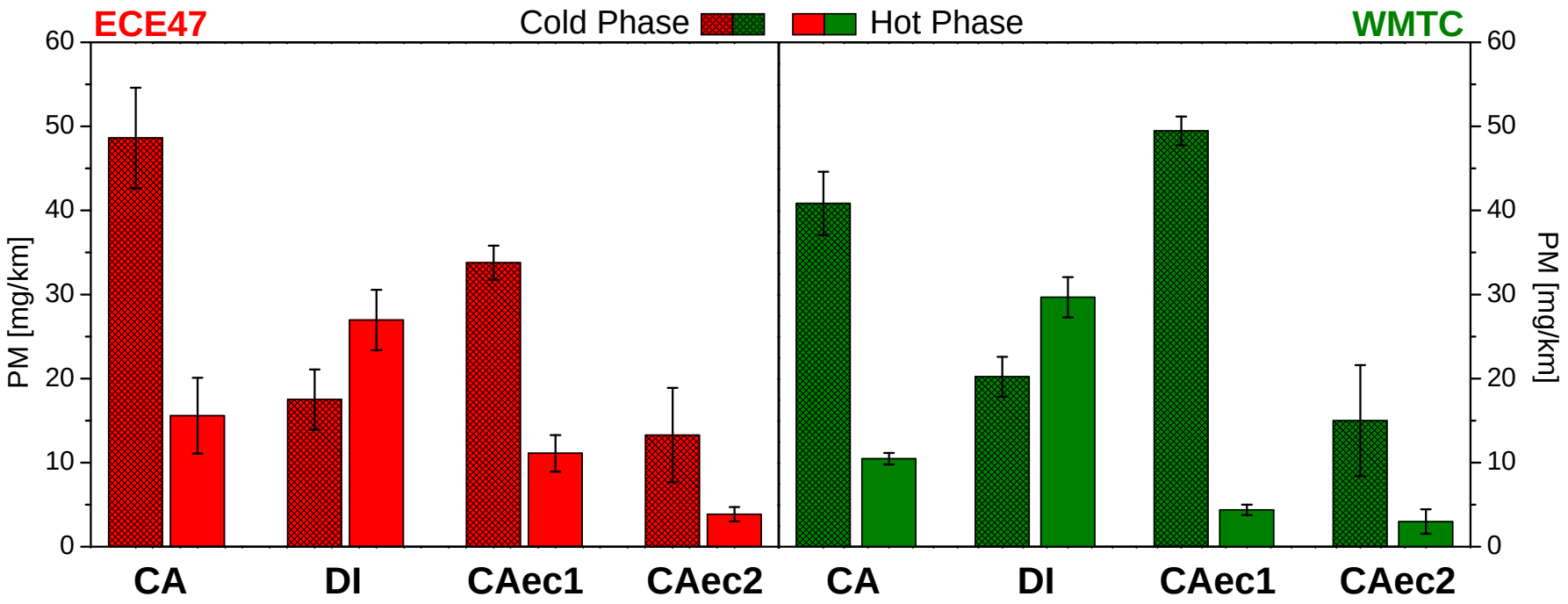
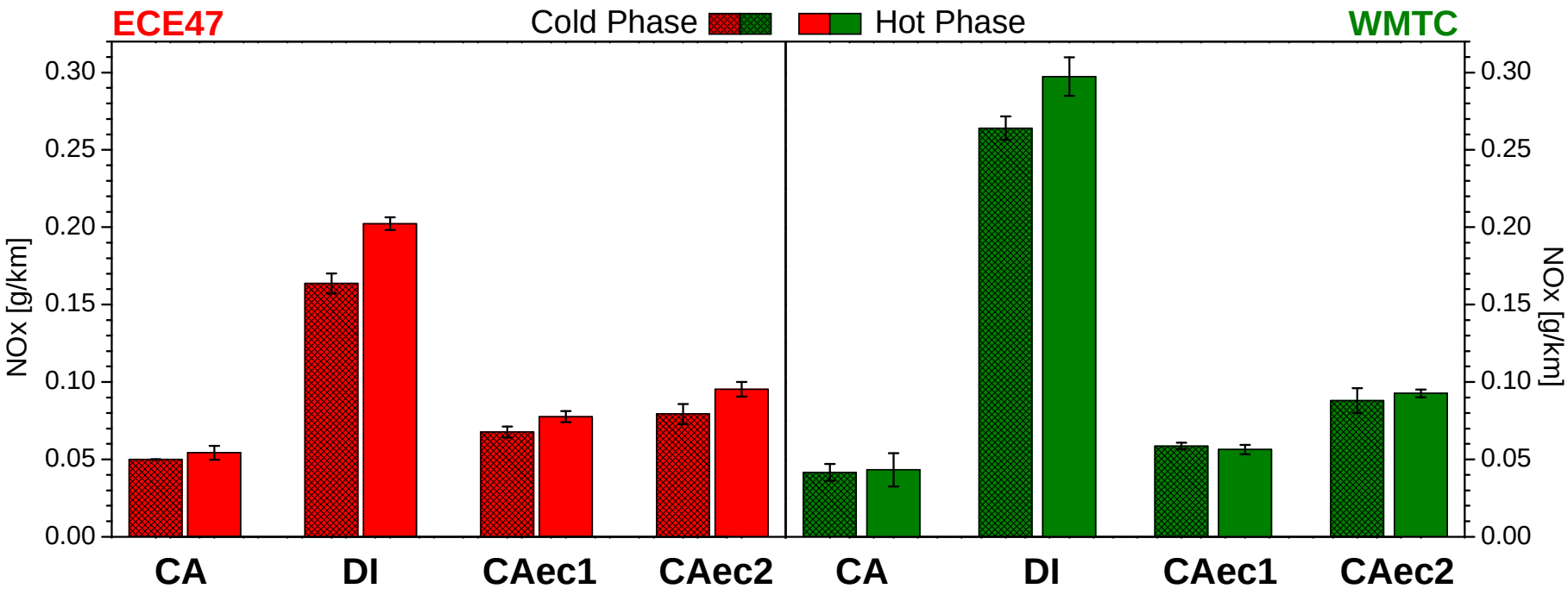


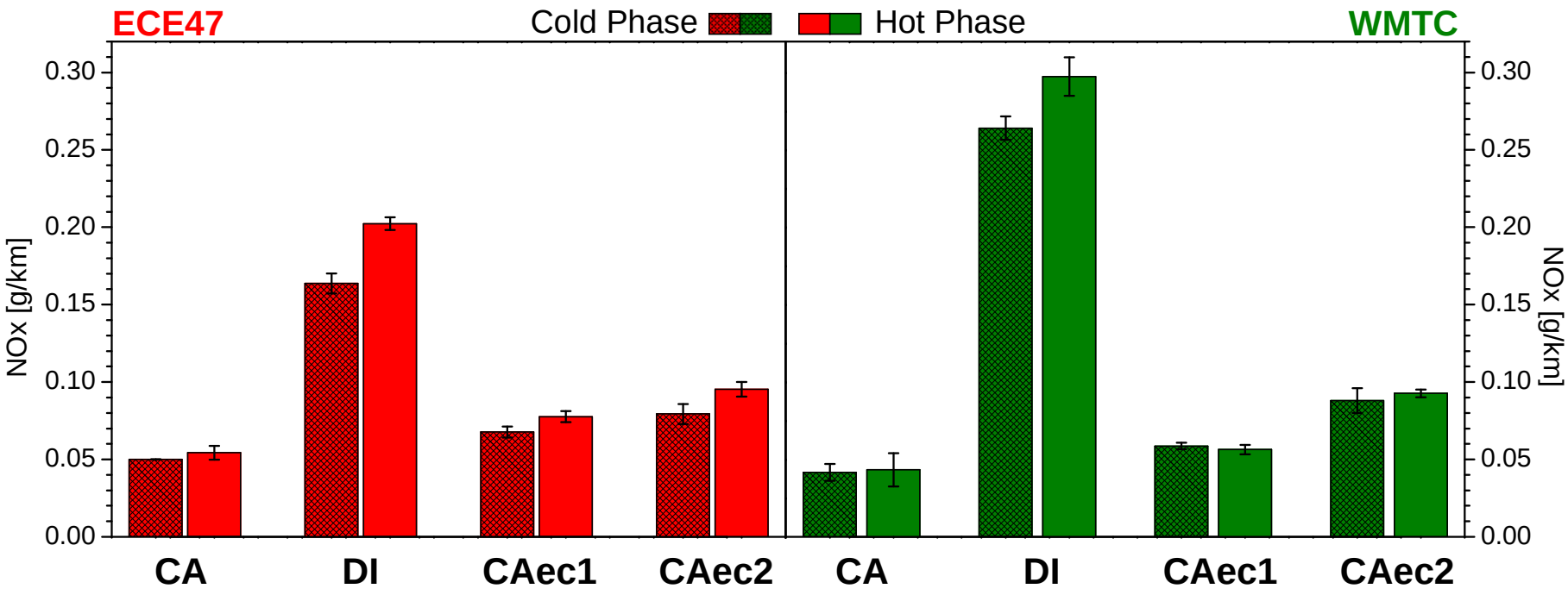
1) CA & CAec: Huge Differences between Cold Phase and Hot Phase
2) DI: Highest Values in Hot Phase
3) Values of CAec2 lower than of CAec1
4) ECE47 and WMTC similar (except CAec1)

Nitrogen Oxides (NOx):



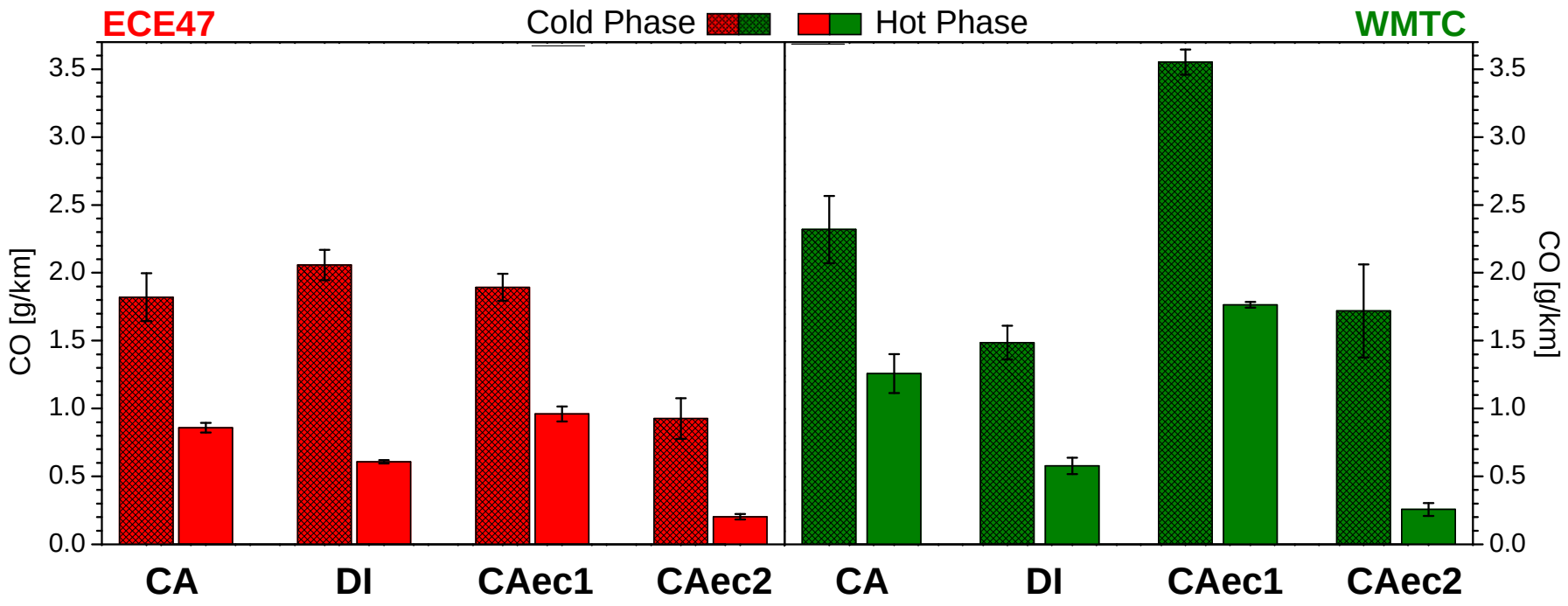
Discussion of Results

Nitrogen Oxides (NOx):



1) DI: Highest Levels; more pronounced for WMTC
2) CA, CAec: Values similar for Engines, Phases, and Cycles
3) DI: Levels increase in Hot Phase

Carbon Monoxide (CO):



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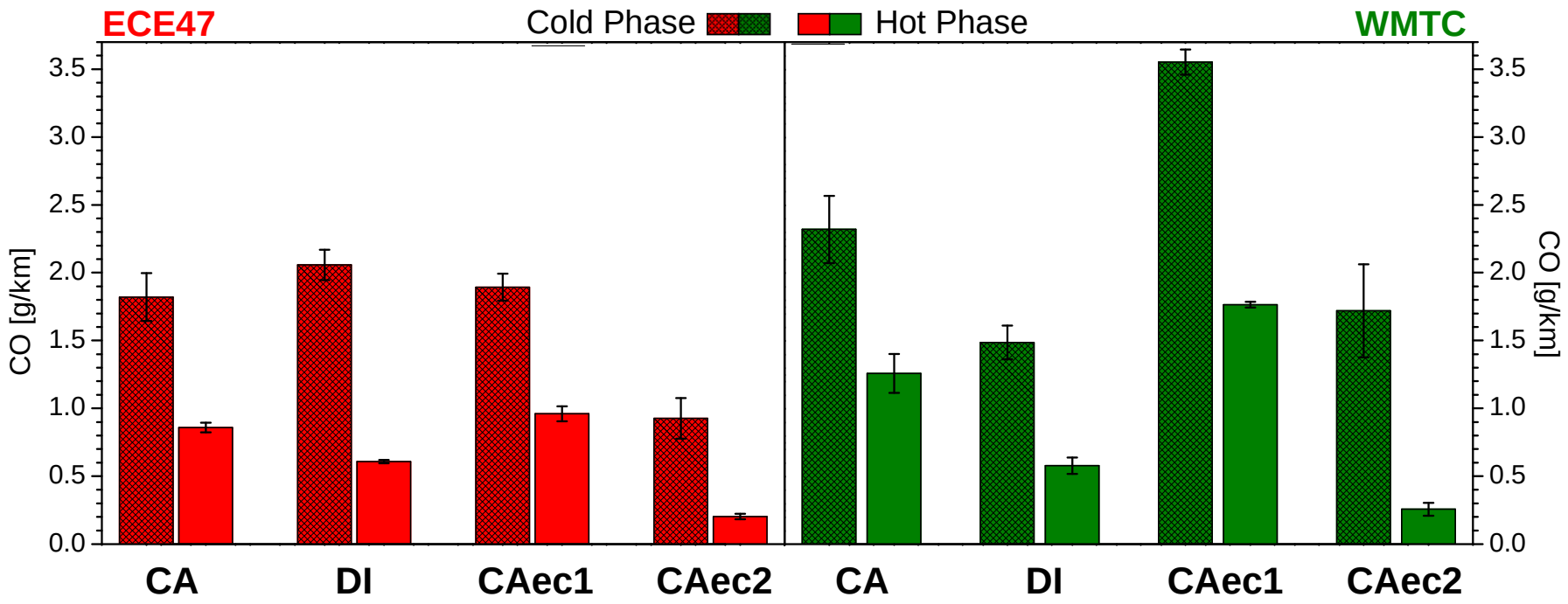
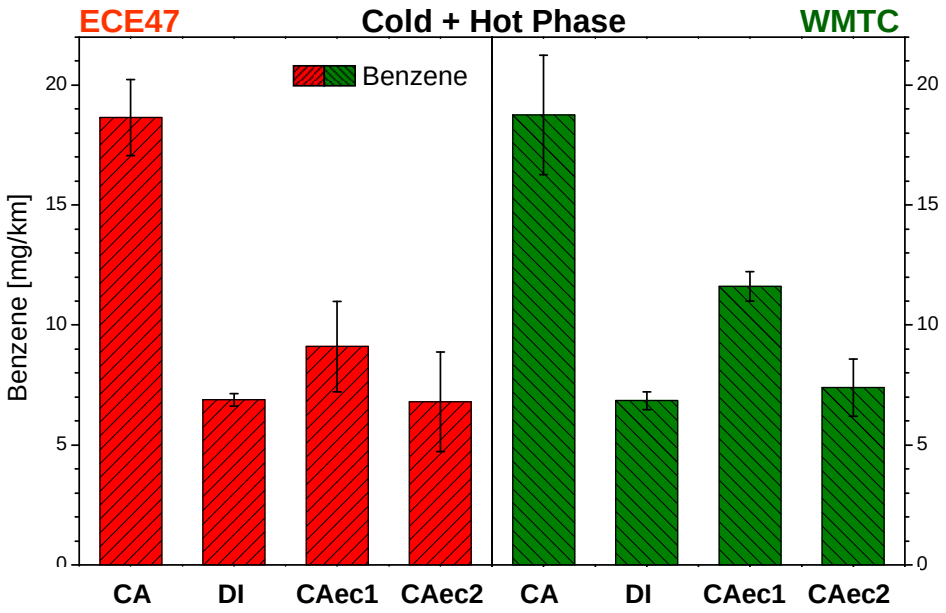


1) ECE47: No Influence of Engine Type (except CAec2)
2) WMTC different to ECE47; especially for CAec

Discussion of Results



Benzene:

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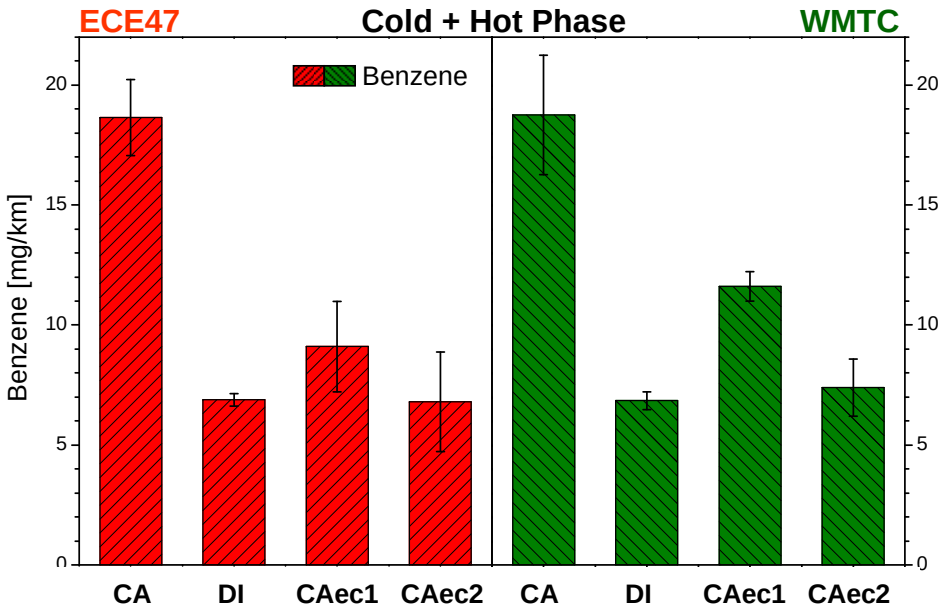

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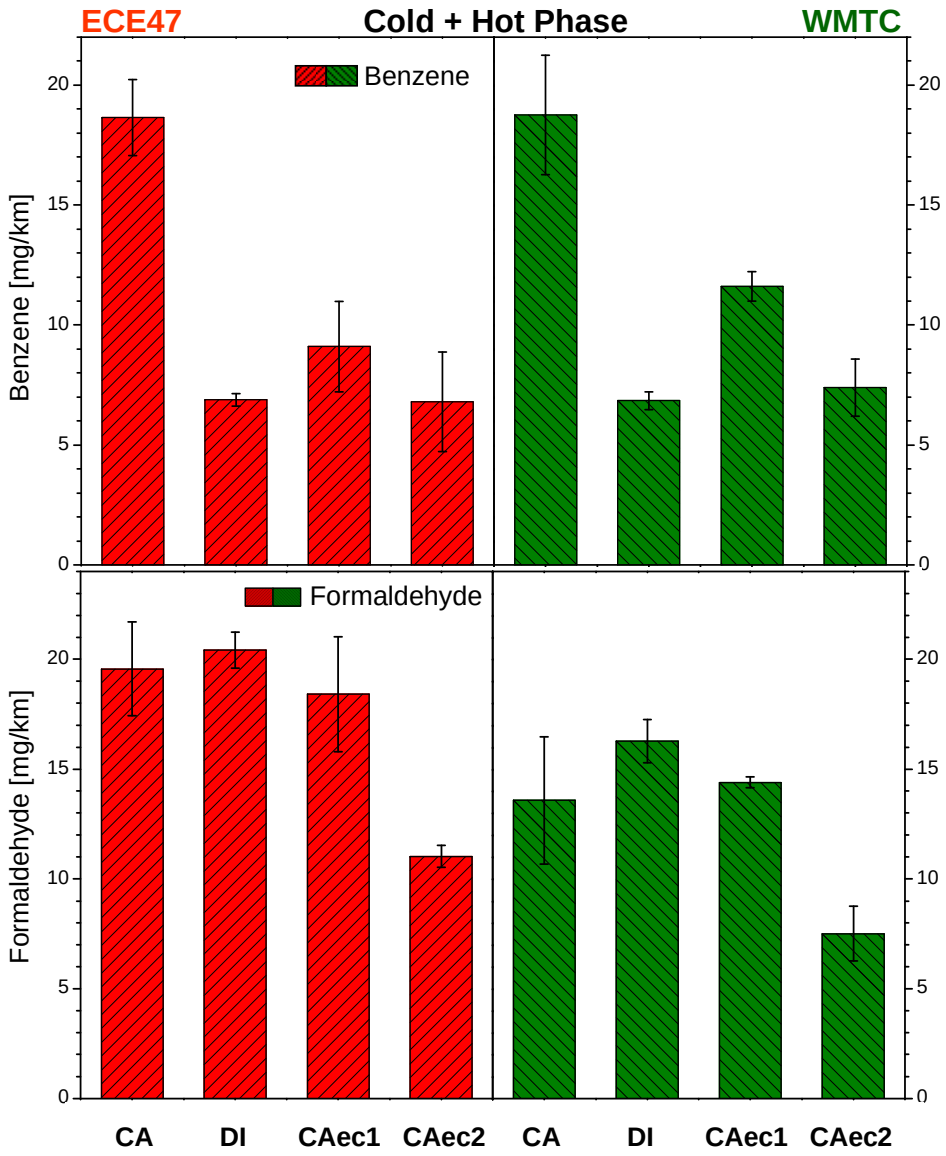

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Formaldehyde:

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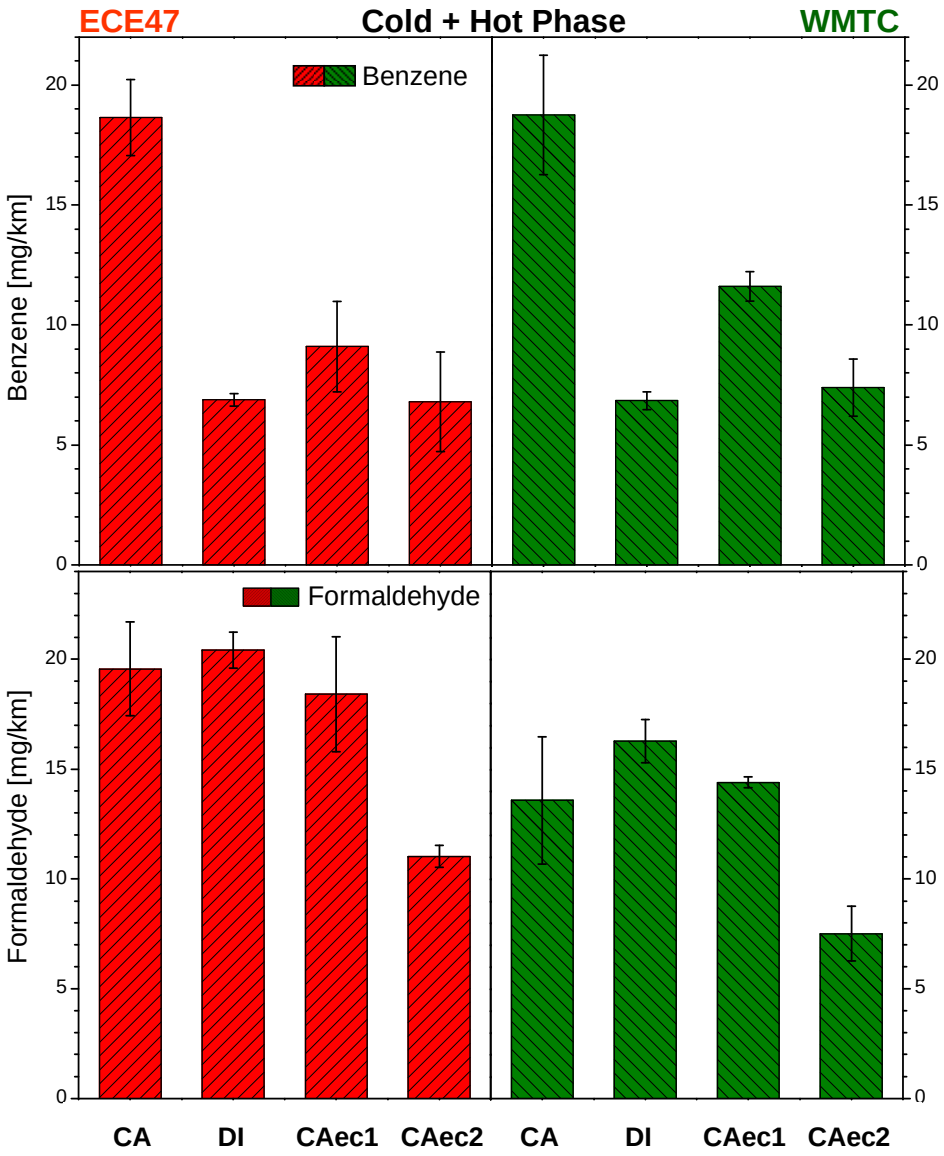

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Formaldehyde:

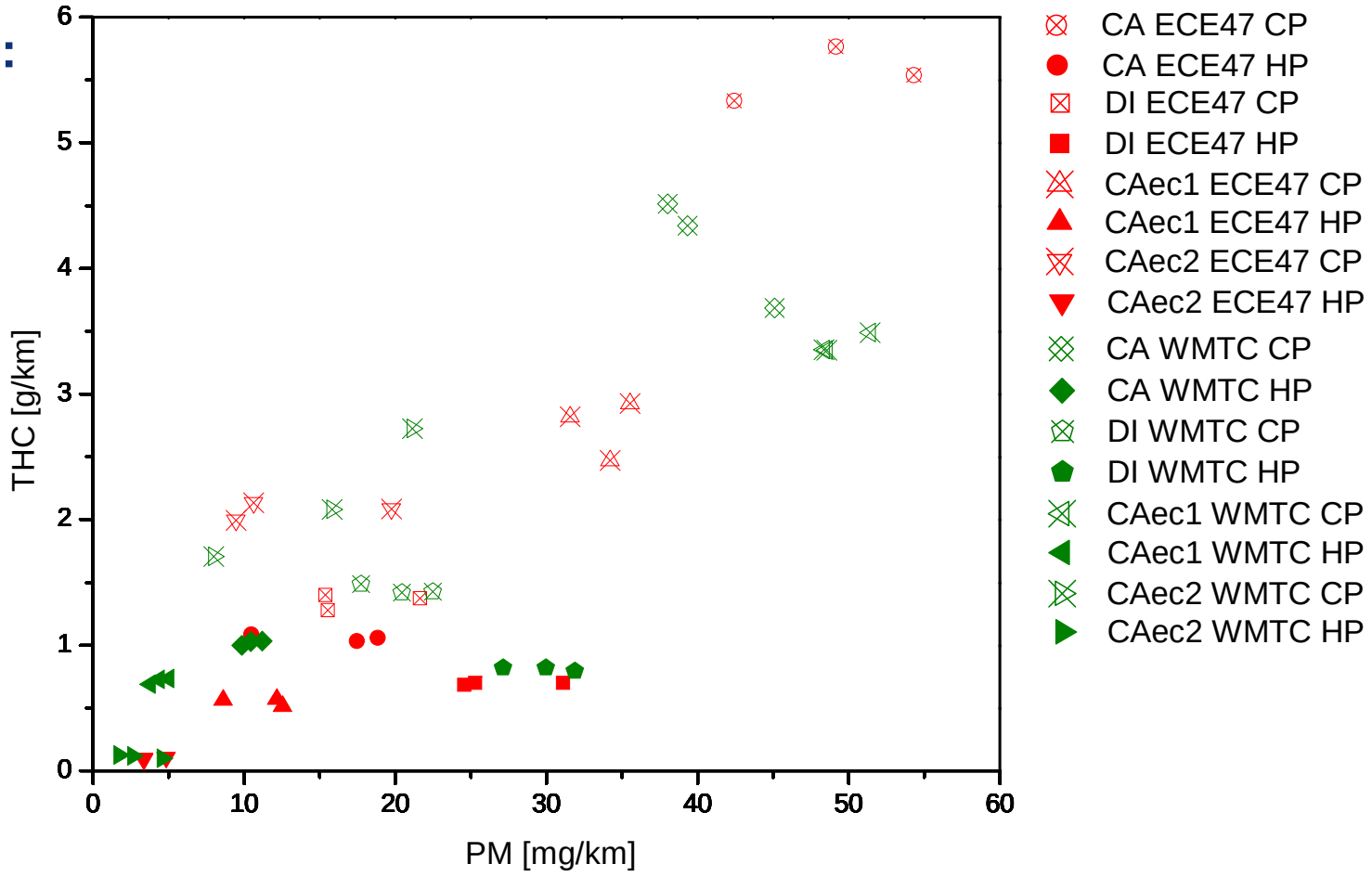
1) CA, DI, CAec1: No Difference
2) WMTC: Levels lower
3) CA: Emission Factor of Benzene and Formaldehyde in same Range

Correlation of THC vs. PM:

Does Regulation of THC automatically regulate PM?

Discussion of Results

THC vs. PM:



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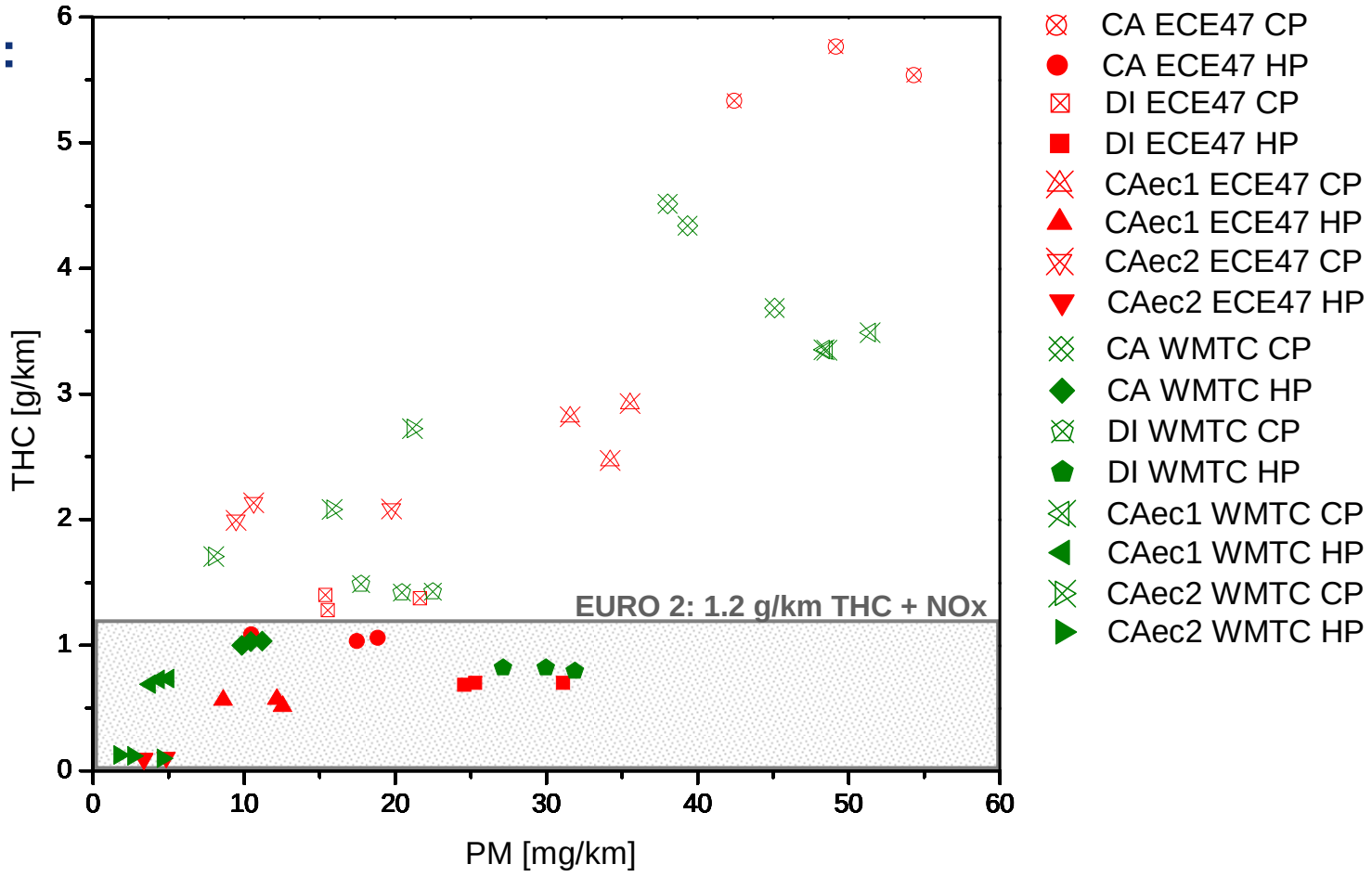

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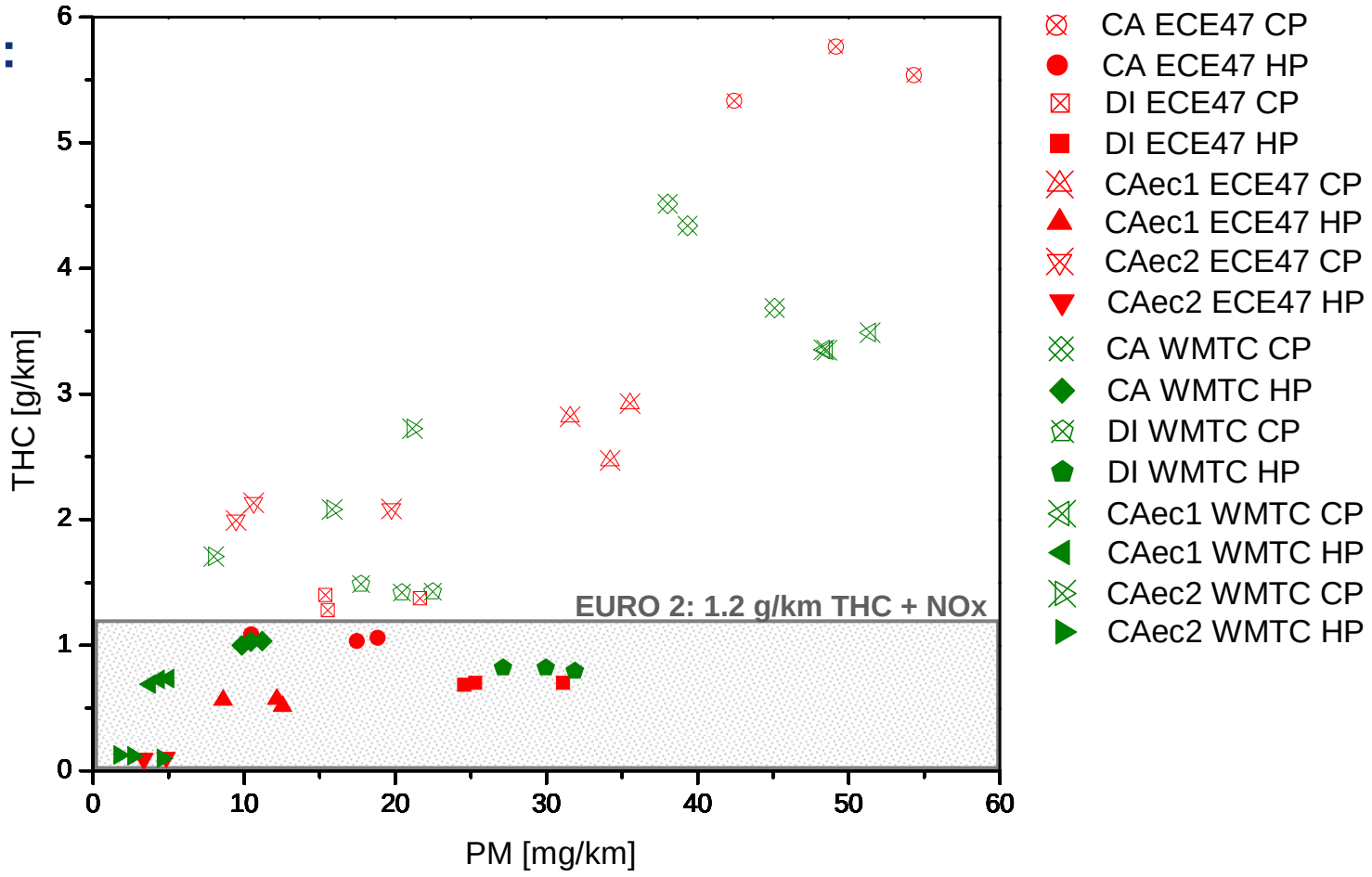

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2) PM of Hot Phase spreads wide Range

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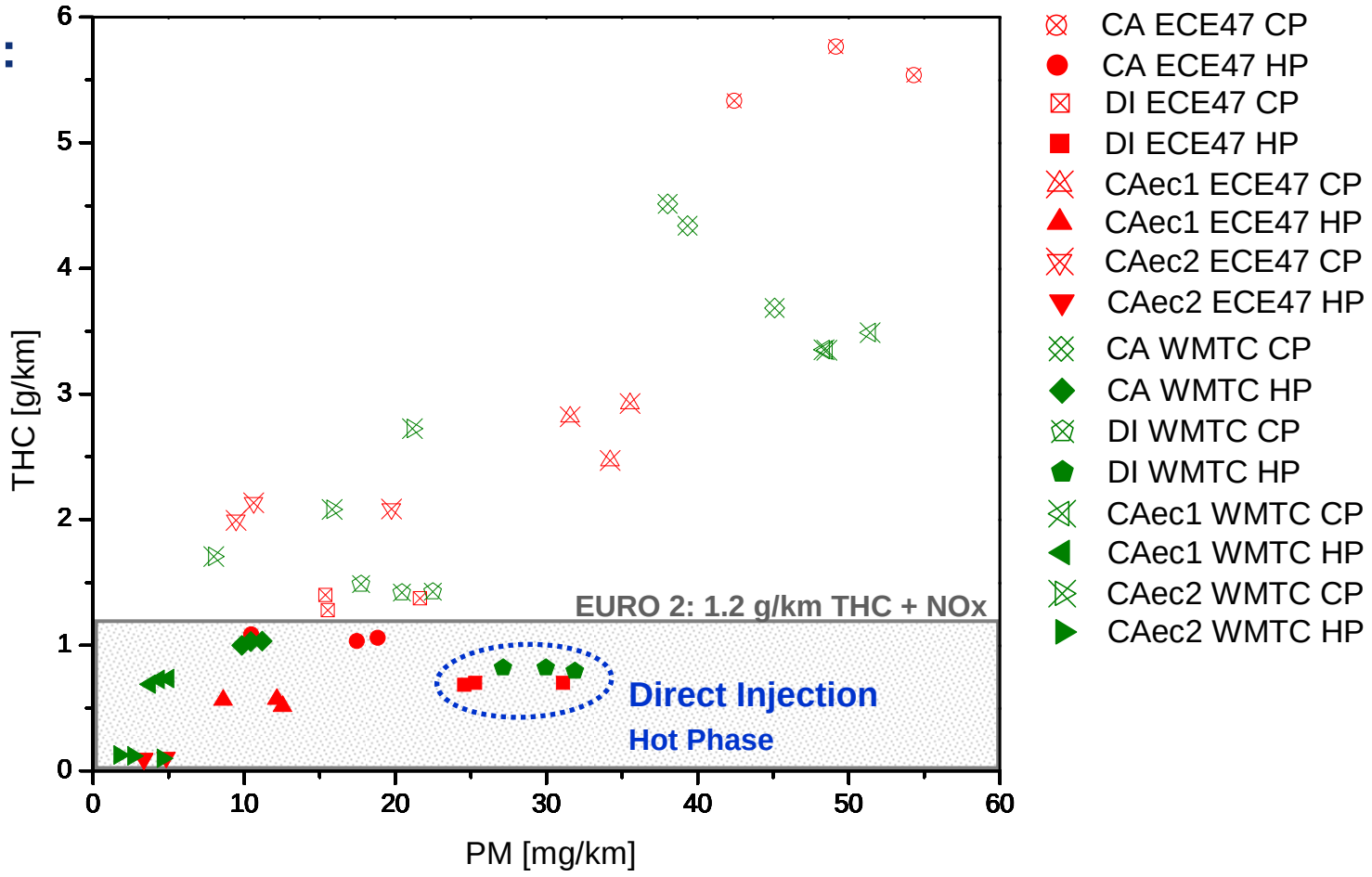

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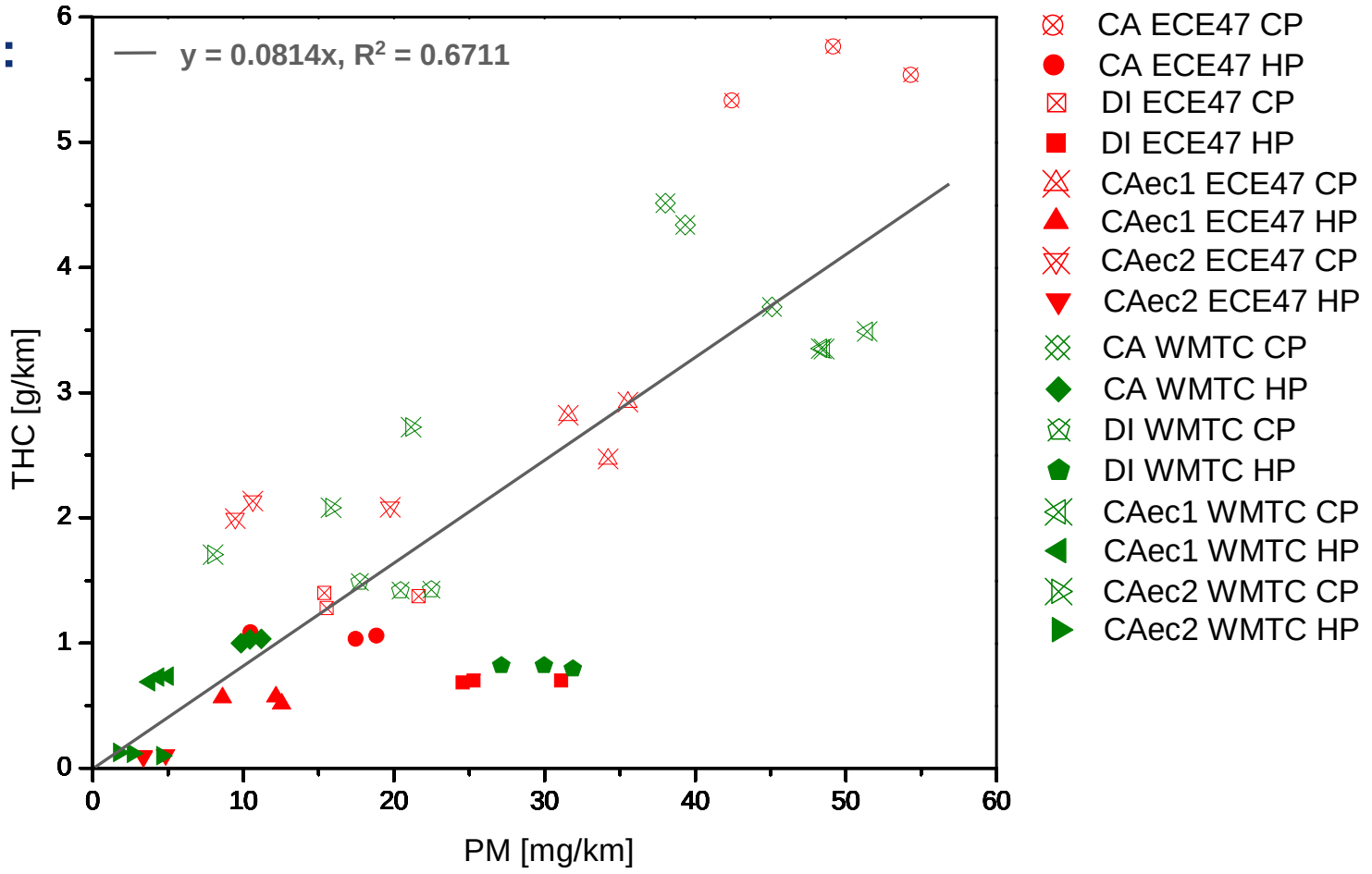

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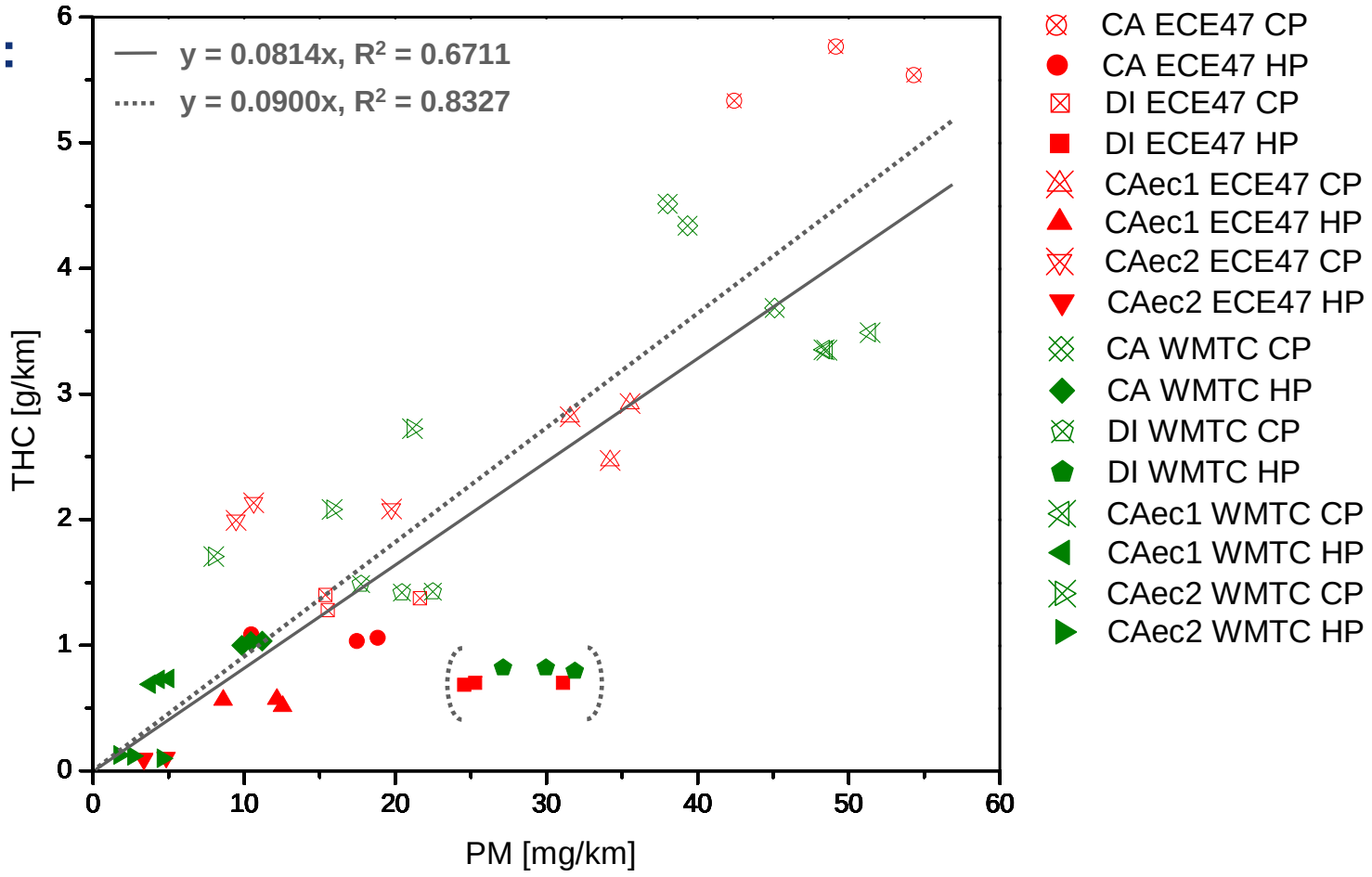

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- Engine Types: Exhaust composition different
  a) CA: high in VOC, OFP
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  c) CAec1/CAec2: Modification reduces most Constituents; little Effect on VOC & NOx

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  a) CO, Carbonyls for all Engines
  b) CAec1
  c) DI NOx

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- Regulation of THC alone might not be sufficient for PM

Thank you for your Attention!

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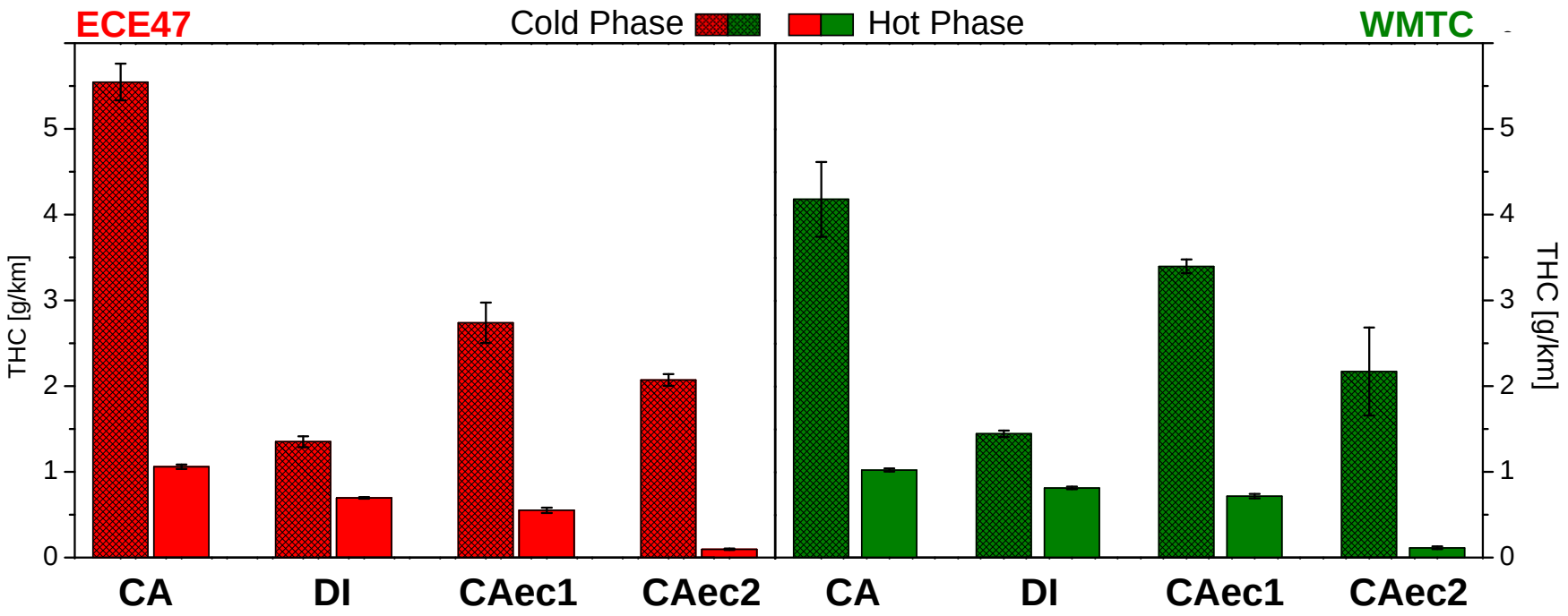
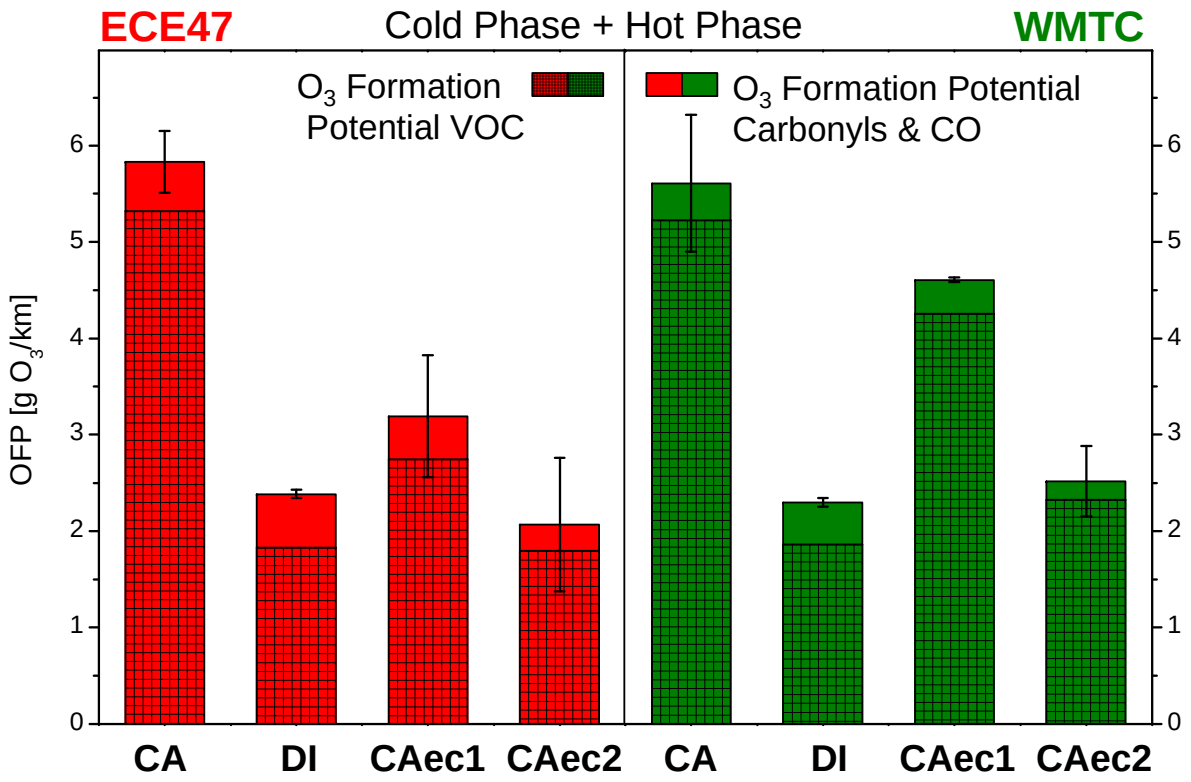
Discussion of Results

Total Hydrocarbons (THC):

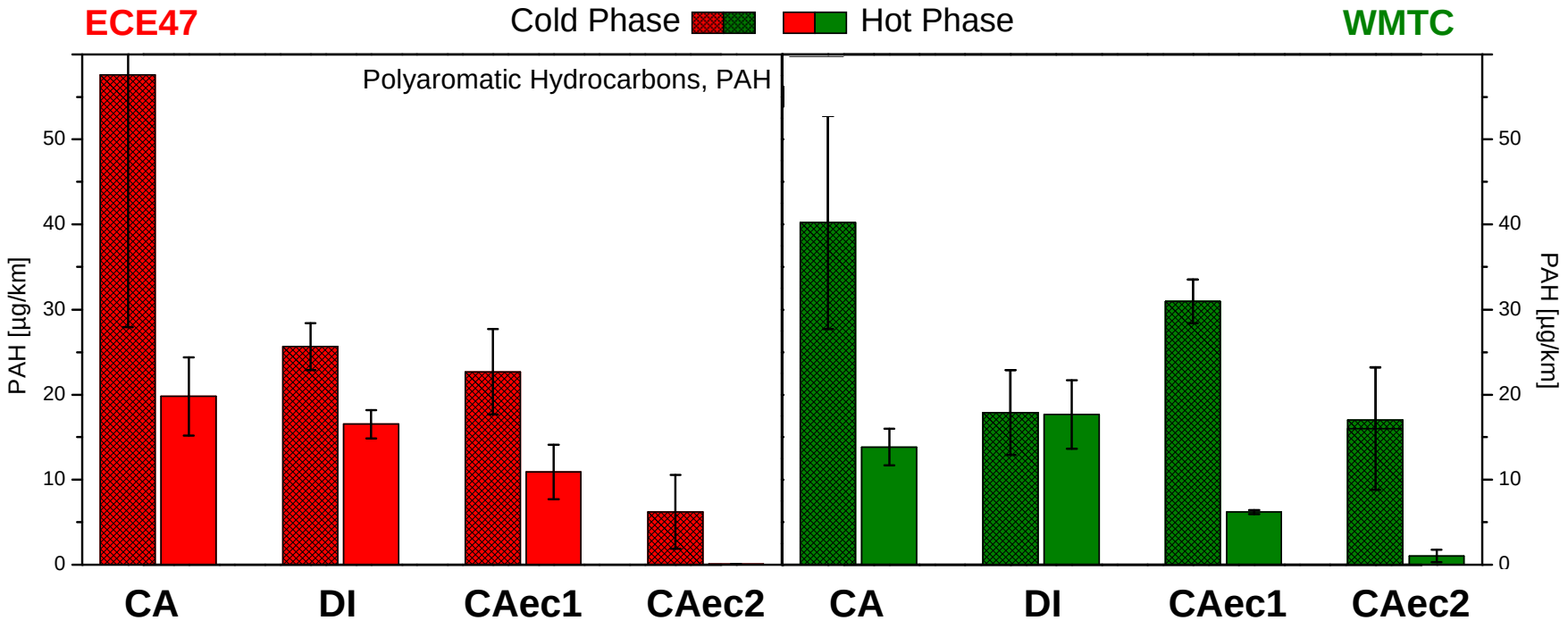


1) CA: Tremendous Difference between Cold Phase and Hot Phase
2) DI: Difference between Cold Phase and Hot Phase smaller
3) DI: Lowest Values for Cold Phase
4) Hot Phases of CA, Di, and CAec1 similar (CAec2 low)
5) ECE47 and WMTC similar

Ozone Formation Potential (OFP):



Polyaromatic Hydrocarbon (PAH):



Carbon Dioxide (CO_2):