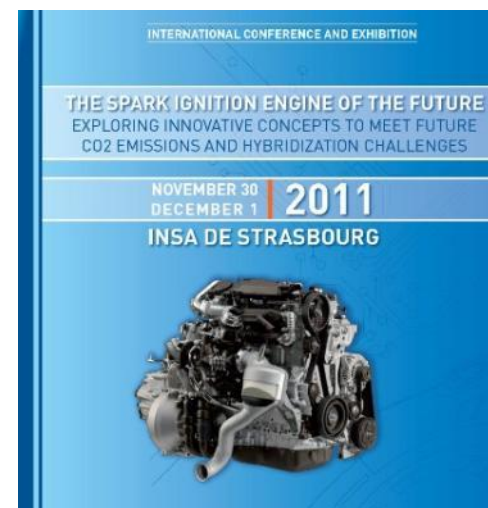


# Regulated and Non-Regulated Emissions of Selected State-of-the-Art European Mopeds

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Association for Emissions Control by Catalyst AISBL



# Association for Emissions Control by Catalyst (AECC) AISBL

AECC members: European emissions control companies



*Technology for exhaust emissions control on all new cars  
(OEM and Aftermarket) and an increasing number of  
buses & commercial vehicles, non-road applications and motorcycles.*















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# Content

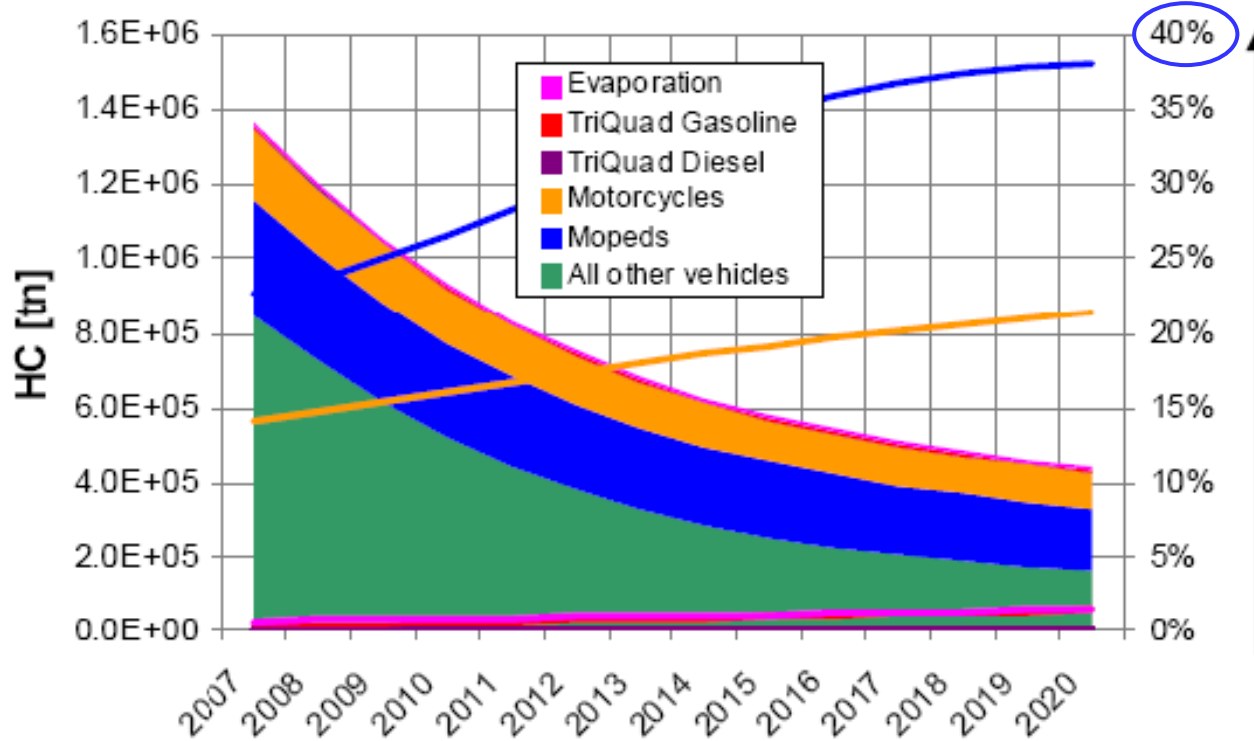
- Powered-Two Wheelers EU legislation
- Moped test program
  - Selection of vehicles
  - Test cycles and equipment
  - Regulated emissions
  - Non-regulated particulate mass and particle number emissions
- Conclusions

# Current L-Category Types (Motorcycles and Mopeds)

| Category | Vehicle Name         | Characteristic Vehicles  |   | Category  | Vehicle Name      | Characteristic Vehicles   |   |
|----------|----------------------|--|---|---|-------------------|---|---|
| L1e      | Moped                |   |  | L5e   | Motor tricycle    |  |  |
| L2e      | 3-wheel moped        |   |   | L6e   | Light quadricycle |  |  |
| L3e      | Motorcycle           |   |  | L7e   | Heavy quadricycle |  |  |
| L4e      | Motorcycle + sidecar |  |   | <p>Mopeds: max. speed 45km/h<br/>max capacity: 50cc (or 4kW electric motor)</p> |                   |   |   |

Source: European Commission, Citizens summary: EU proposal for a Regulation on L-category vehicles, October 2010

# L-Category Share of HC Emissions



L-Category vehicle  
hydrocarbon (HC)  
emissions share

(% of all road transport  
HC emissions in the EU)

Source: European Commission, Citizens summary: EU proposal for a Regulation on L-category vehicles, October 2010

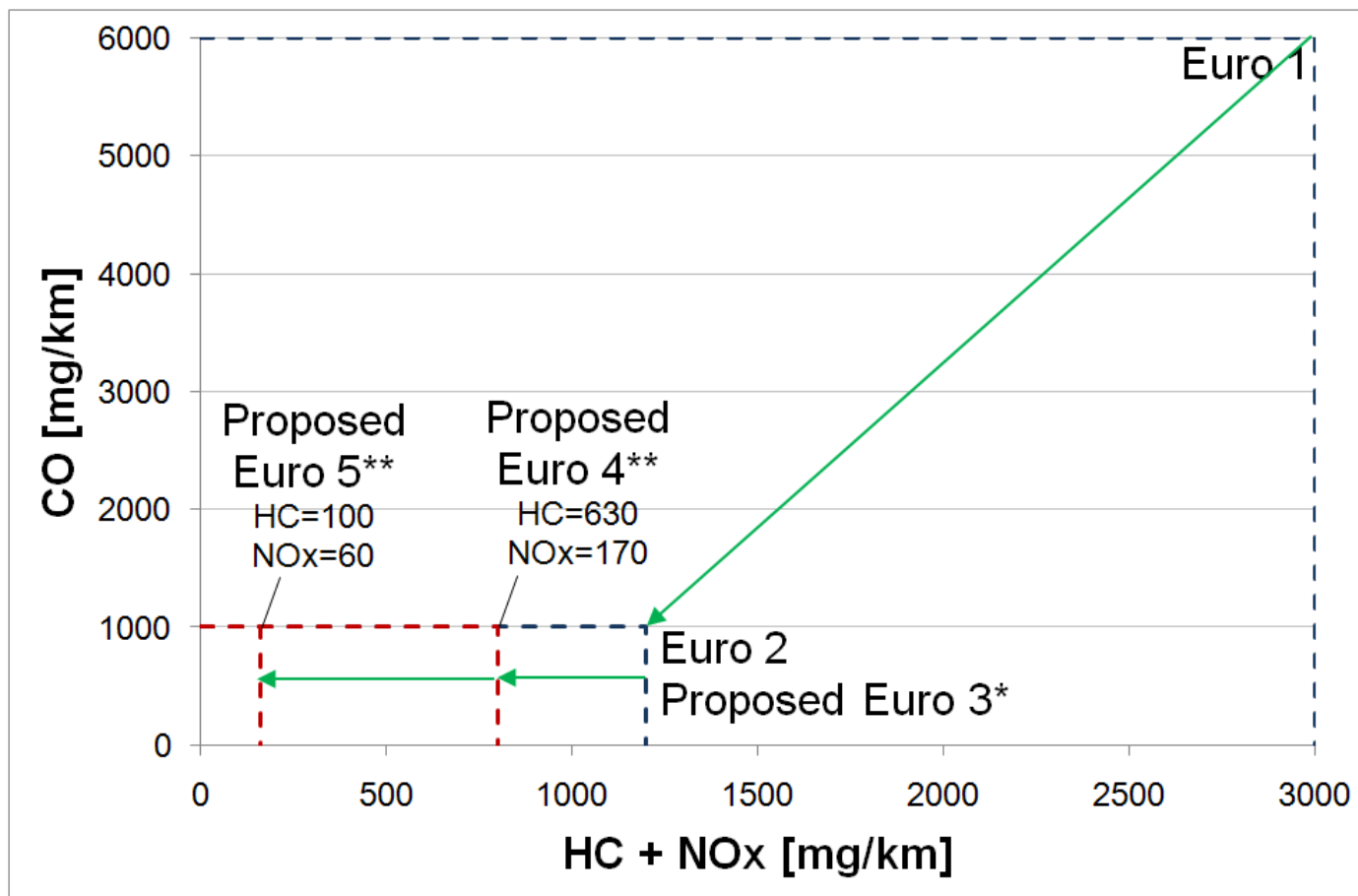
# Current and Proposed Limits for Mopeds

## (COM(2010)0542 )

| L1Be 2-wheel moped (PI) |      |     |      |     |        |     |                 |
|-------------------------|------|-----|------|-----|--------|-----|-----------------|
| mg/km                   | CO   | THC | NMHC | NOx | HC+NOx | PM  |                 |
| Euro 2 (2002)           | 1000 | -   | -    | -   | 1200   | -   | hot start R.47  |
| Euro 3 (2014)           | 1000 | -   | -    | -   | 1200   | -   | cold start R.47 |
| Euro 4 (2017)           | 1000 | 630 | -    | 170 | -      | -   | cold start R.47 |
| Euro 5 (2020)           | 1000 | 100 | 68   | 60  | -      | 4.5 | revised WMTC    |

| L2e 3-wheel moped (PI) |      |     |      |     |        |     |                 |
|------------------------|------|-----|------|-----|--------|-----|-----------------|
| mg/km                  | CO   | THC | NMHC | NOx | HC+NOx | PM  |                 |
| Euro 2 (2002)          | 3500 | -   | -    | -   | 1200   | -   | hot start R.47  |
| Euro 3 (2014)          | 3500 | -   | -    | -   | 1200   | -   | cold start R.47 |
| Euro 4 (2017)          | 1900 | 730 | -    | 170 | -      | -   | cold start R.47 |
| Euro 5 (2020)          | 1000 | 100 | 68   | 60  | -      | 4.5 | revised WMTC    |

# Moped Emissions Legislation in EU



\* includes cold start

\*\* includes cold start and separate HC and NOx limits.

# Mopeds Specifications

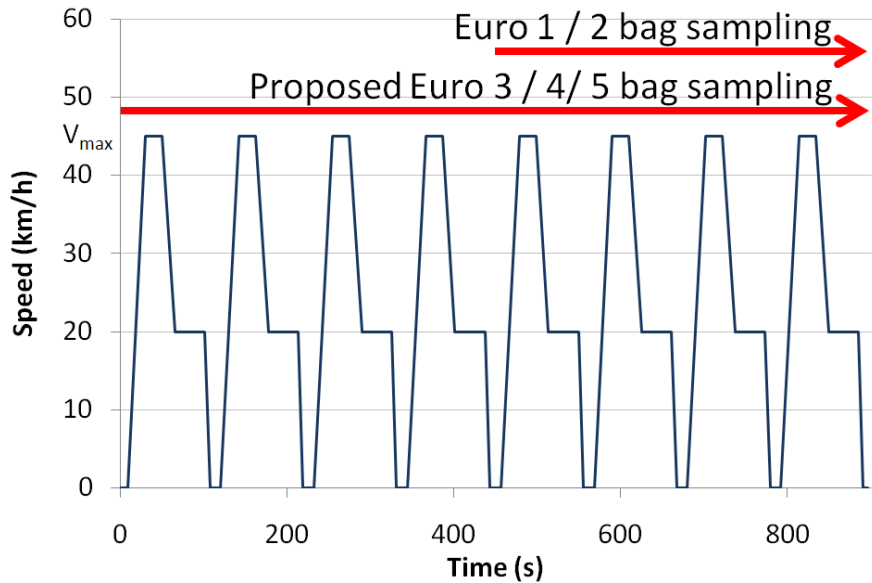
| Vehicle | Technology              | Specifications                                | Mixture preparation   | Exhaust system                  | Max. velocity   | Emission standard                     |
|---------|-------------------------|---|---|---------------------------------|---|---------------------------------------|
| A       | 4-stroke<br>EFI         | 4-stroke / 4-valve SOHC                       | EFI<br>with<br>$\lambda$ -sensor                                  | 3-way<br>catalyst               | 44 km/h<br><br>restricted by leaning                                      | EURO 2<br><br>ECE R47                 |
|         |                         | Power [kW] / [rpm] : 3 / 7500                 |   |                                 |   |                                       |
|         |                         | Cooling : liquid<br>Reference mass [kg] : 85  |   |                                 |   |                                       |
| B       | 4-stroke<br>carburetor  | 4-stroke / 2-valve SOHC                       | carburettor<br>(constant<br>depression)                           | 1 catalyst<br><br>secondary air | 48 km/h<br><br>restricted by ignition<br>retarding                        | EURO 2<br><br>ECE R47                 |
|         |                         | Power [kW] / [rpm] : 2.88 / 8500              |   |                                 |   |                                       |
|         |                         | Cooling : fan<br>Reference mass [kg] : 111    |   |                                 |   |                                       |
| C       | TUG<br>2-stroke<br>LPDI | 2-stroke                                      | <u>L</u> ow <u>P</u> ressure<br><u>D</u> irect <u>I</u> njection  | 1 catalyst                      | 47 km/h<br><br>restricted by leaning                                      | Designed for<br>EURO 3<br><br>ECE R47 |
|         |                         | Power [kW] / [rpm] : 3.7 / 7200               |   |                                 |   |                                       |
|         |                         | Cooling : liquid<br>Reference mass [kg] : 95  |   |                                 |   |                                       |
| D       | 2-stroke<br>carburetor  | 2-stroke                                      | carburettor<br>(slider)   | 1 catalyst<br><br>secondary air | >50 km/h<br>unrestricted. Throttle<br>closed at 50km/h for<br>these tests | Designed for<br>EURO 3<br><br>ECE R40 |
|         |                         | Power [kW] / [rpm] : 2.3 / 6250               |   |                                 |   |                                       |
|         |                         | Cooling : fan<br>Reference mass [kg] : 103    |   |                                 |   |                                       |
| E       | 2-stroke<br>ASDI        | 2-stroke                                      | <u>A</u> ir <u>S</u> upported<br><u>D</u> irect <u>I</u> njection | 1 catalyst                      | 42 km/h<br><br>restricted by leaning                                      | EURO 2<br><br>ECE R47                 |
|         |                         | Power [kW] / [rpm] : 4 / 7750                 |   |                                 |   |                                       |
|         |                         | Cooling : liquid<br>Reference mass [kg] : 108 |   |                                 |   |                                       |



# Test Cycles

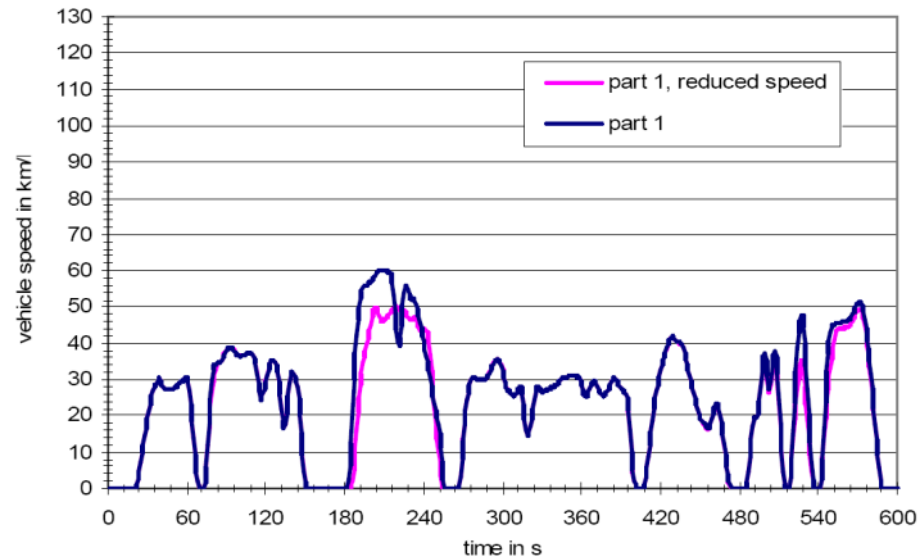
## R47

- Legal requirement .
- Emissions measured from cold start.
- Euro 3 and beyond: 30% weighting for first 4 cycles and 70% for last 4 cycles.



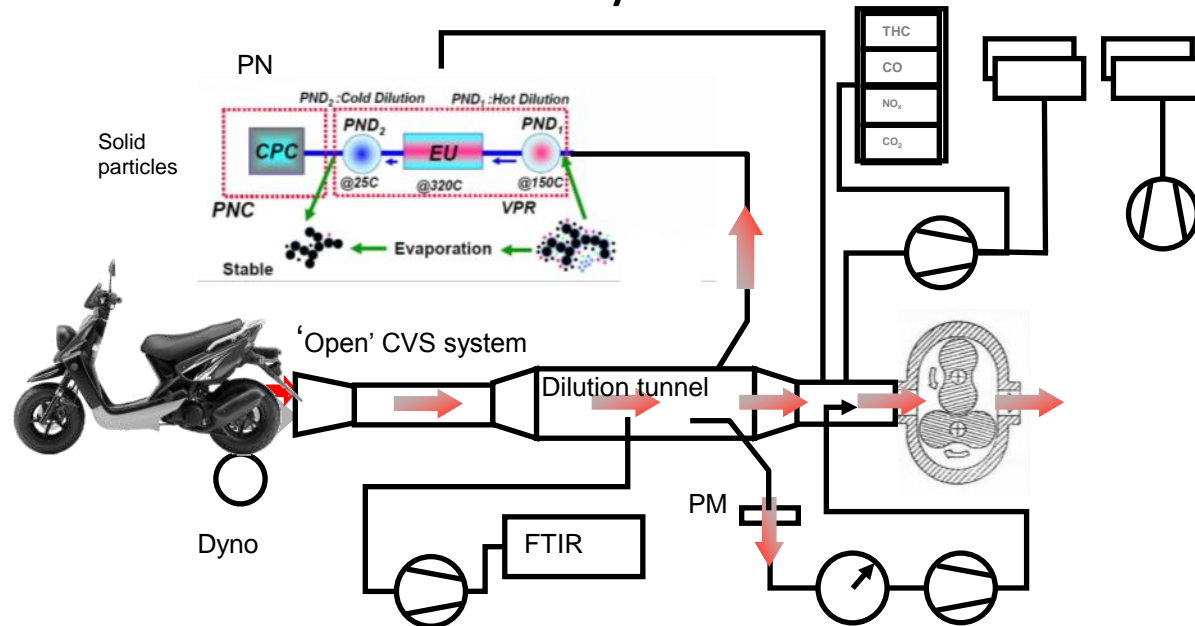
## WMTC

- Not developed for mopeds.
- Category 1 motorcycles (50-150 cc,  $50 < V_{max} < 100$  km/h).
- Part 1 , reduced speed.
- 2 repeats (cold start + hot start), 50/50 weighting.



# Test Equipment

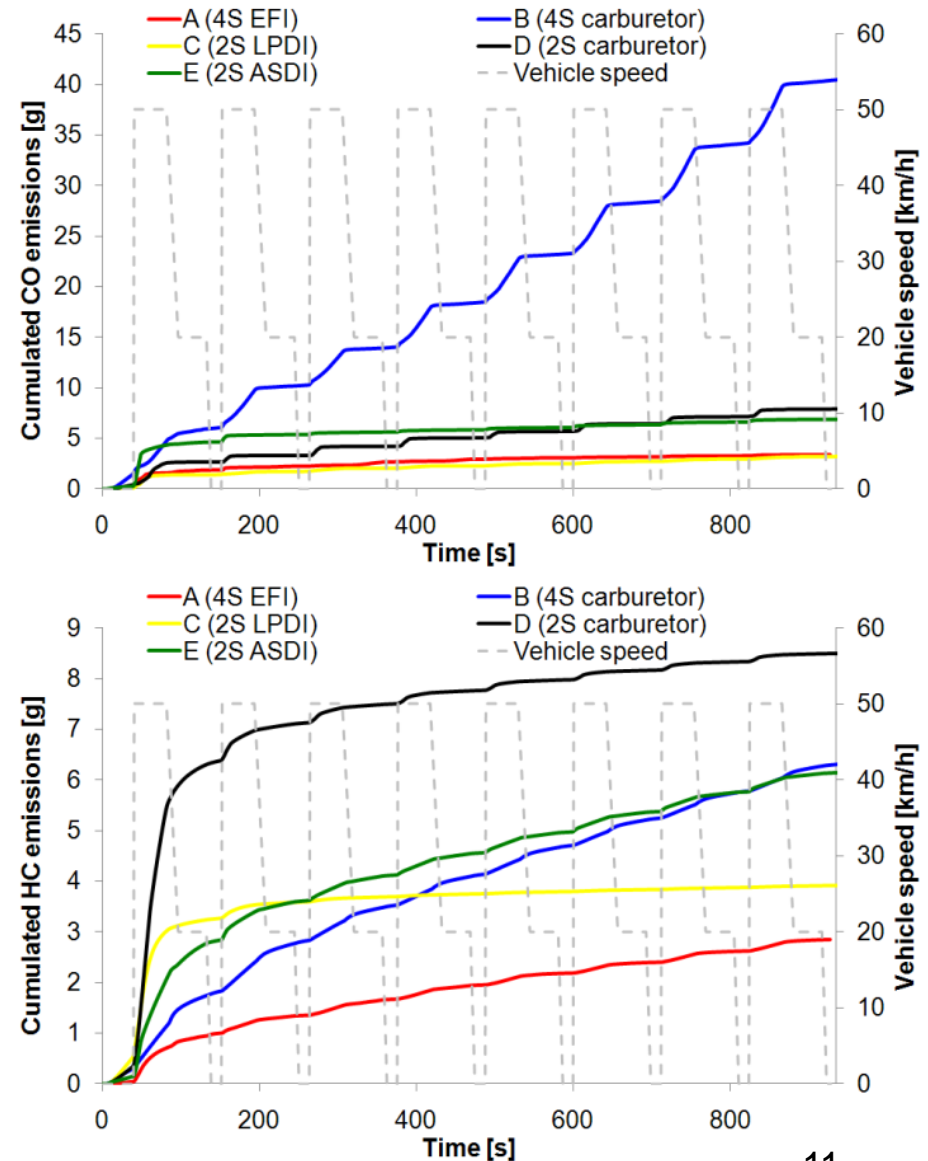
- 'Open' CVS avoids introduction of pressure depression in exhaust which would increase secondary air flow and so reduce emissions results.



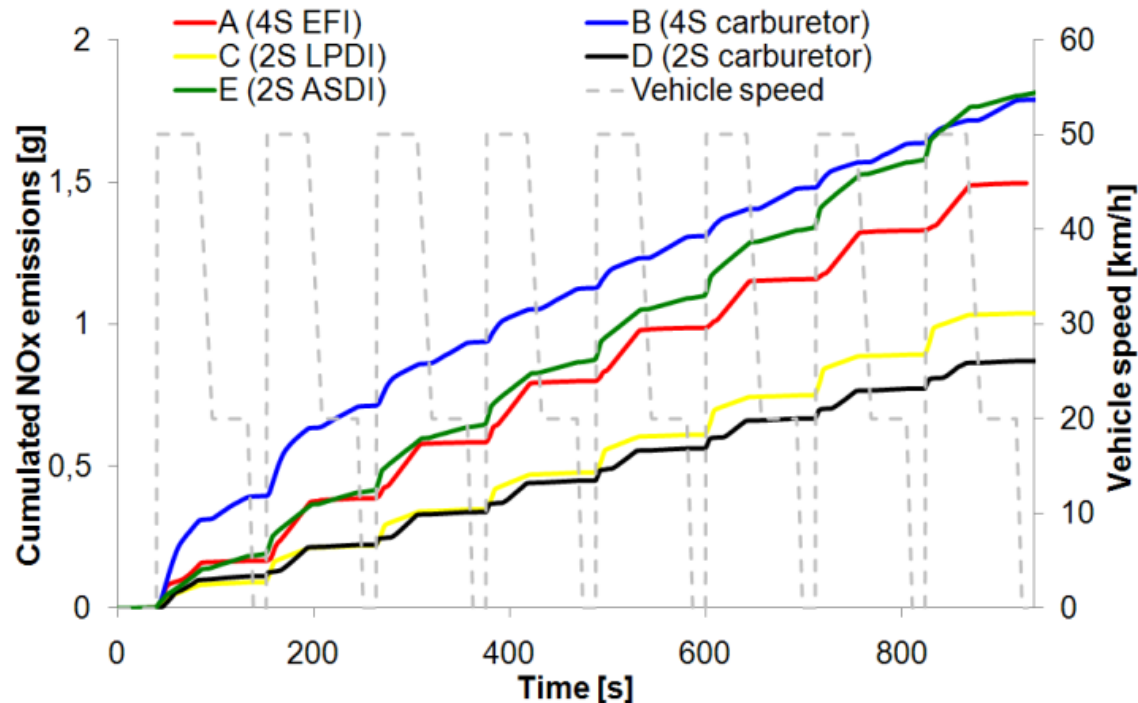
- Measurement of regulated emissions + FTIR for N species.
- Pallflex 47mm filter plates for particulate mass.
  - Sampling over the full test cycle.
- PN analysis using dilution/heating system with TSI CPC 3775 analyzer.

# Cumulative CO and HC Emissions on R47

- CO emissions highlight the effect of the poor catalyst position on the 4-stroke carburetor bike.
- For HC the effect of cold start is obvious for all bikes, but particularly for the 2-stroke carburetor.

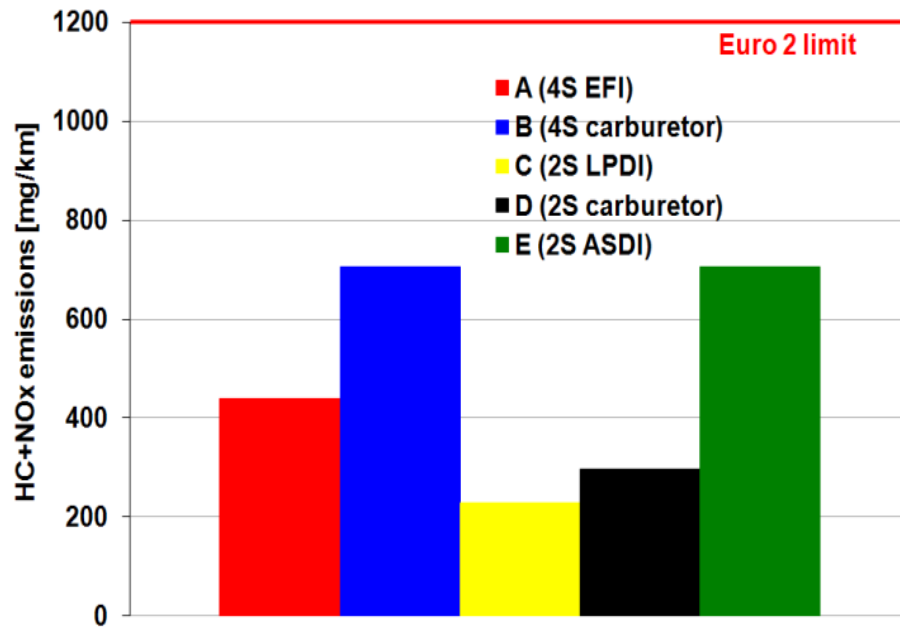


# Cumulative NOx Emissions on R47

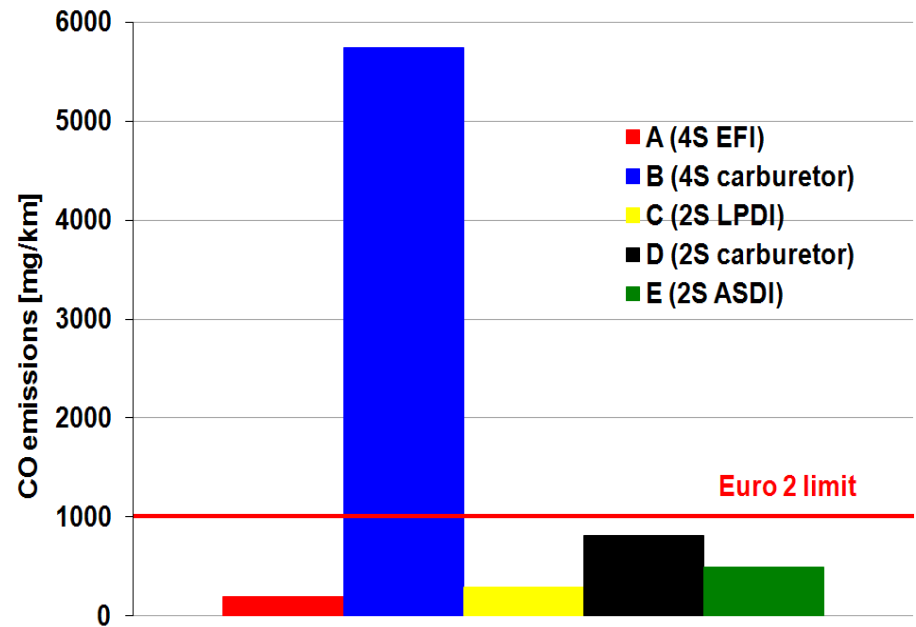


- Despite having a  $\lambda$  sensor and TWC, NOx control is poor for the 4-stroke EFI.
- NOx are mainly produced during accelerations, for all mopeds.

# Regulated Emissions compared to Euro 2 (100% hot phase)



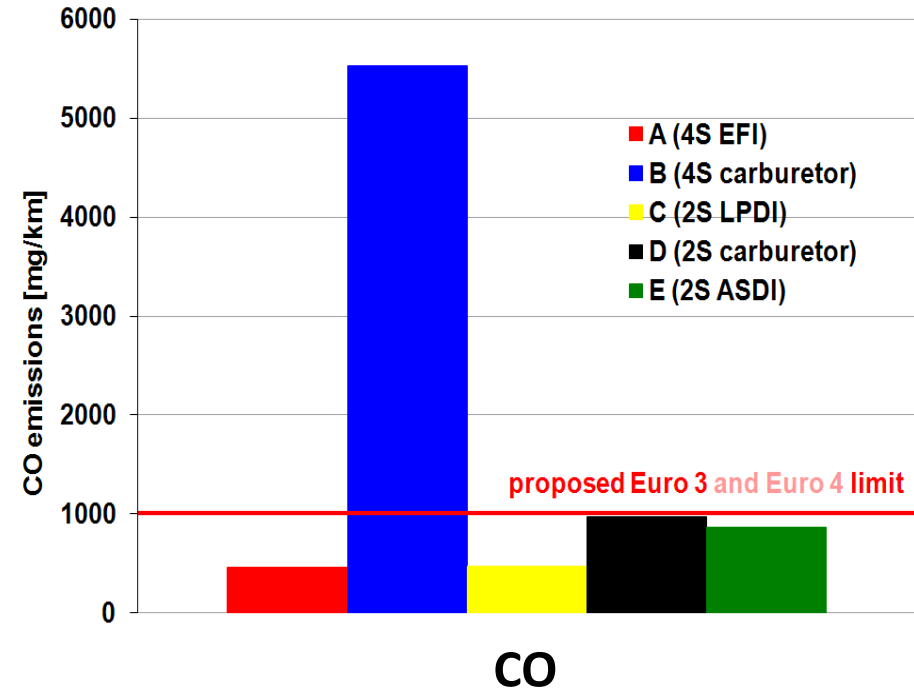
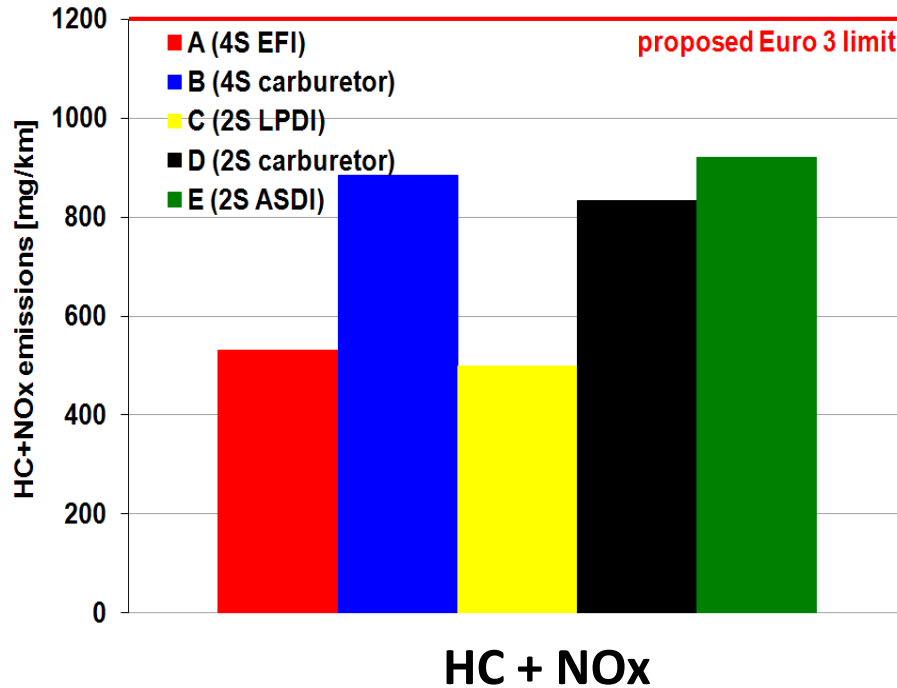
HC + NOx



CO

- The 4-stroke carburetor vehicle exhibited CO emissions several times higher than the legislative limit, despite procured new and only degreened for 250 km.
- All except the 4-stroke carburetor vehicle met the Euro 2 limits.

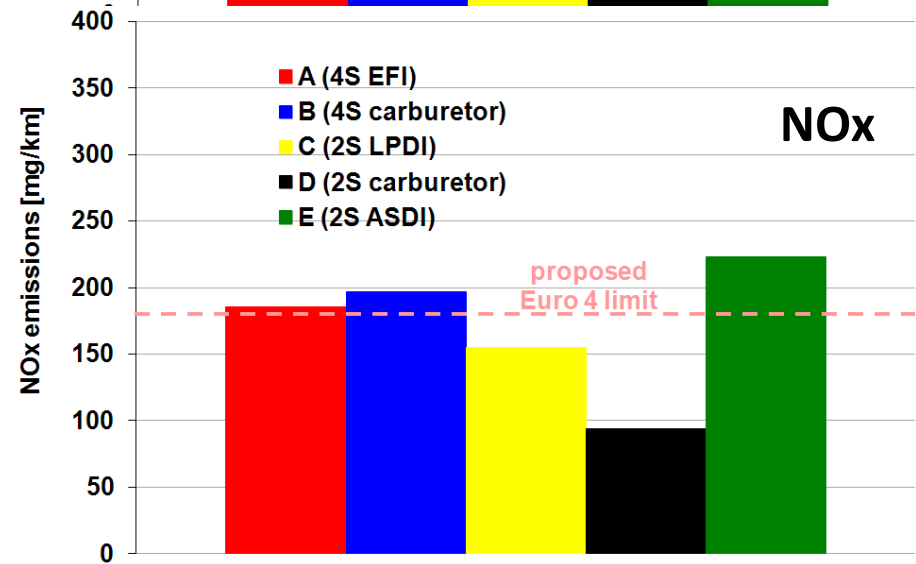
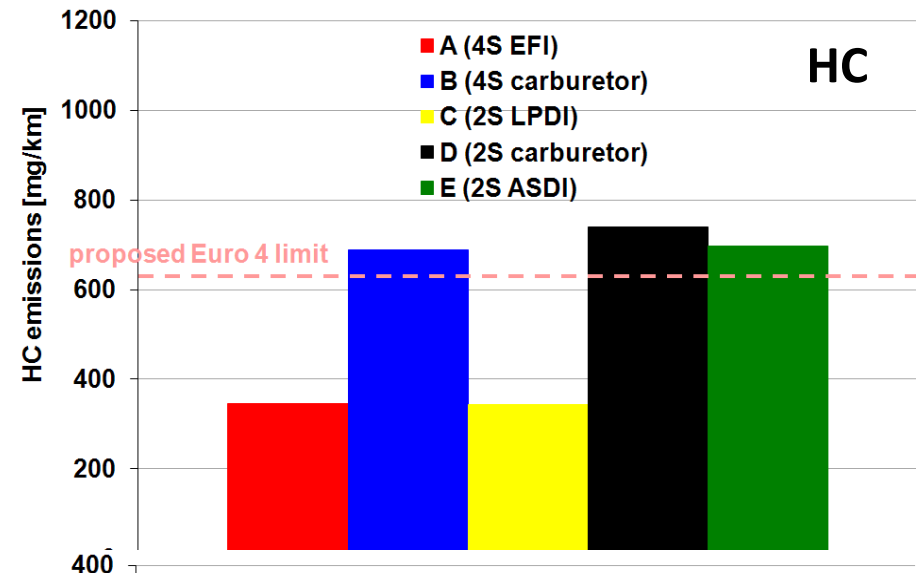
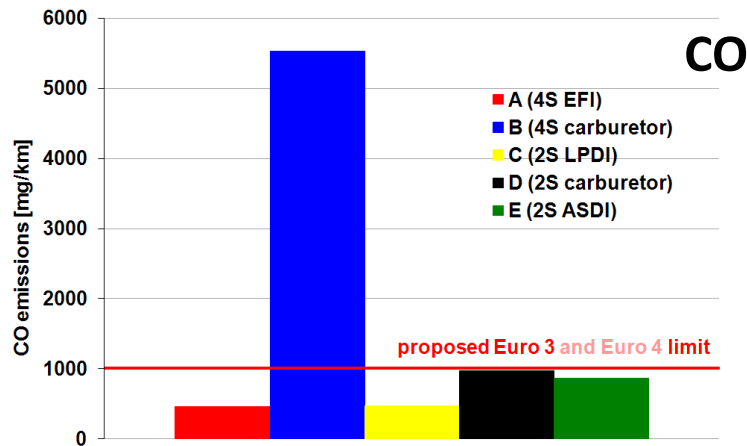
# Regulated Emissions compared to Proposed Euro 3 (30% cold phase)



- Without durability and assuming 30% cold weighting, all vehicles except the 4-stroke carburetor vehicle met the proposed limits for Euro 3.
- The 2-stroke carburetor vehicle was very close to the CO limit.

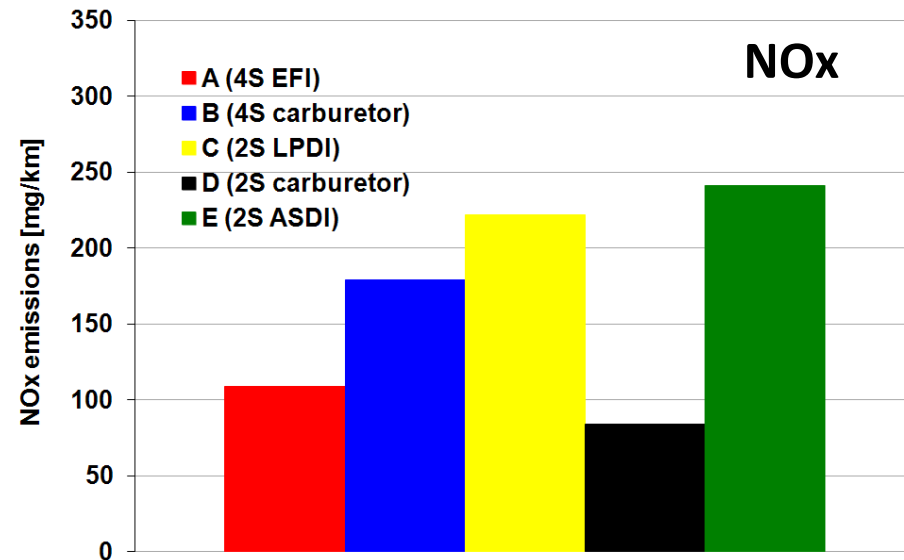
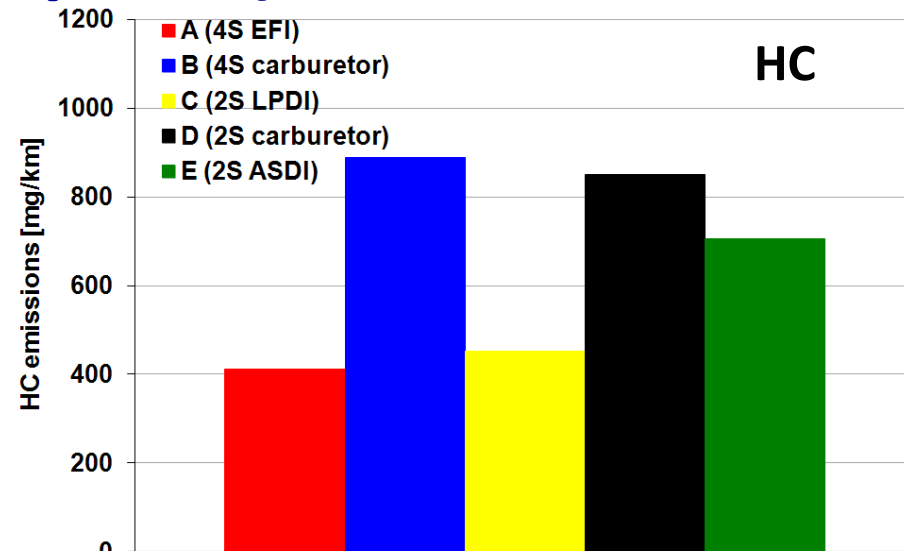
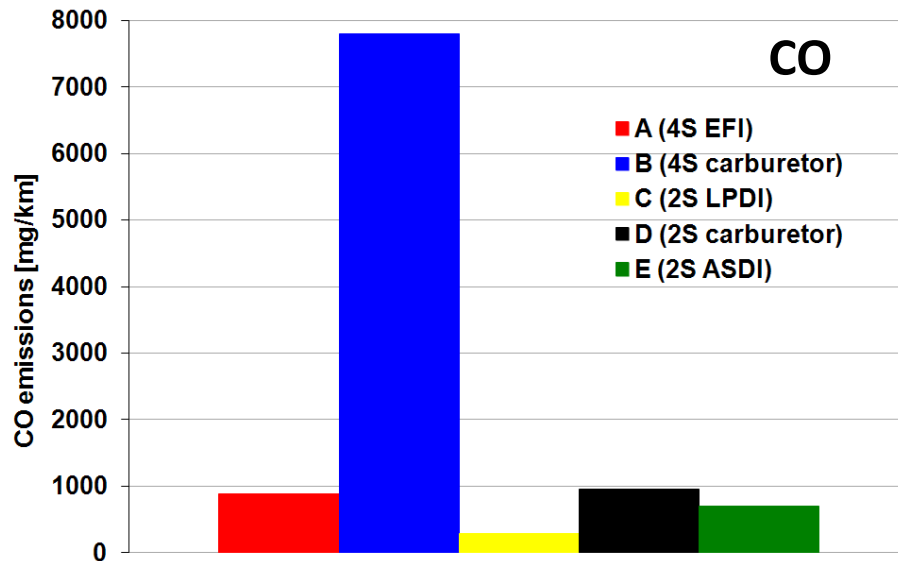
# Regulated Emissions compared to Proposed Euro 4 (30% cold phase)

- Without durability and assuming 30% cold weighting, the 2-stroke LPDI already meets the proposed Euro 4 limits.
- Generally, little emissions improvement needed to meet the proposed Euro 4 limits.



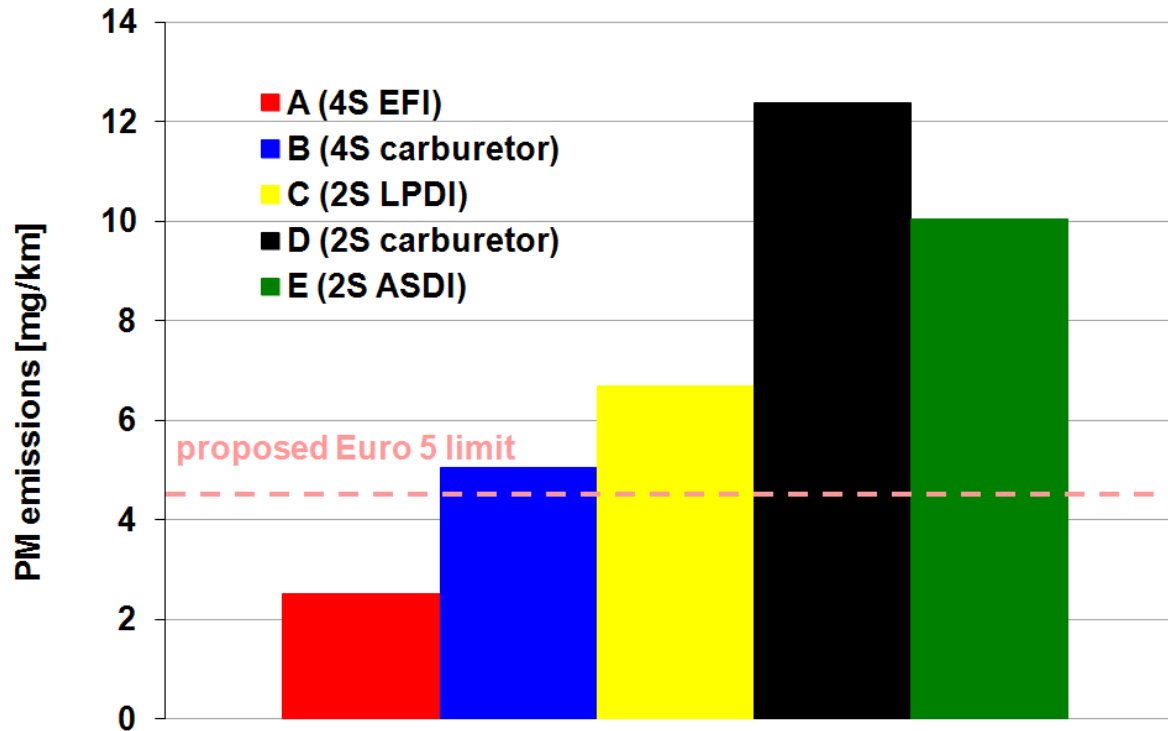
# Regulated Emissions measured on WMTC (50% cold phase)

- Similar cold start and catalyst light-off performance than on R47.
- Confirmation of bad performance of 4-stroke carburetor.
- R47 driving pattern may be more appropriate.





# Particulate Mass Emissions

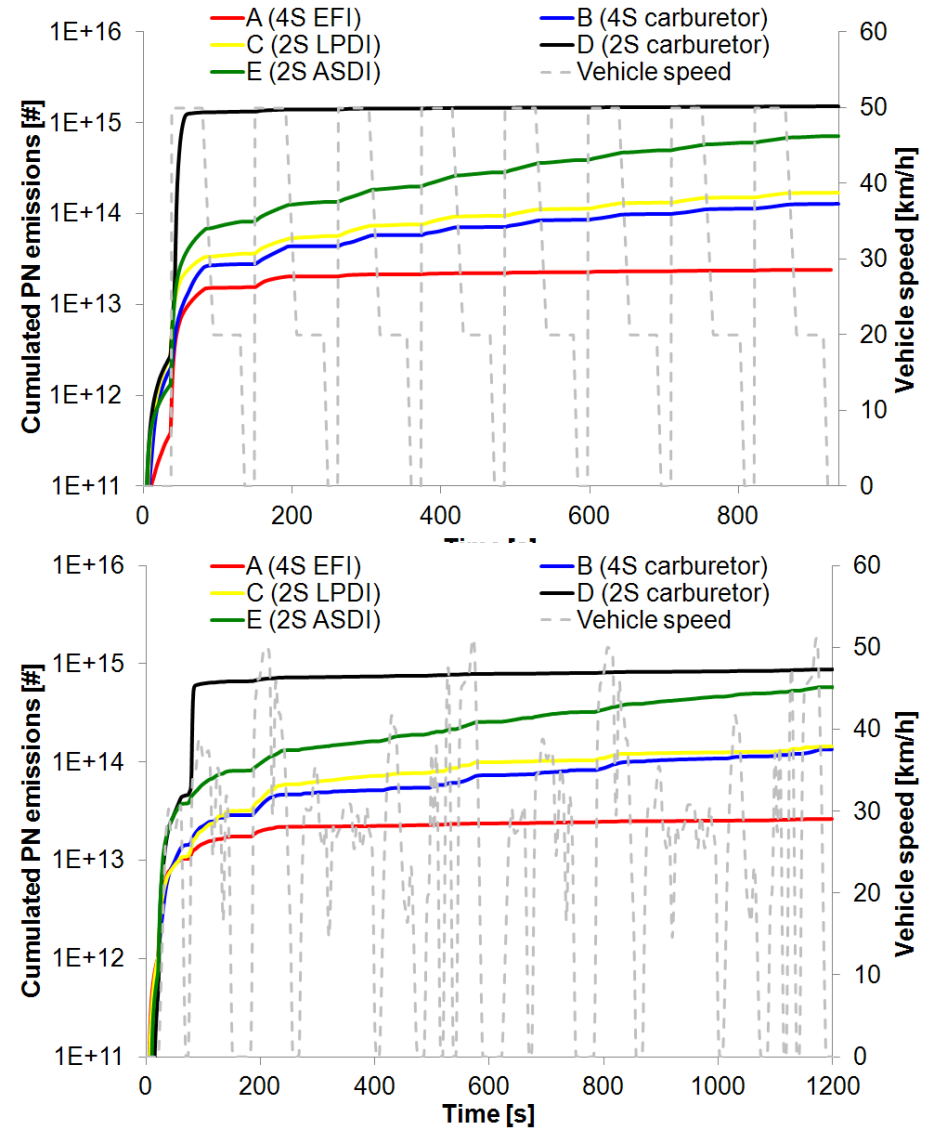


| ECE R47                | Pallflex EMFAB<br>4000 lpm sampling |
|------------------------|-------------------------------------|
| 4-stroke<br>EFI        |                                     |
| 4-stroke<br>carburetor |                                     |
| 2-stroke<br>LPDI       |                                     |
| 2-stroke<br>carburetor |                                     |
| 2-stroke<br>ASDI       |                                     |

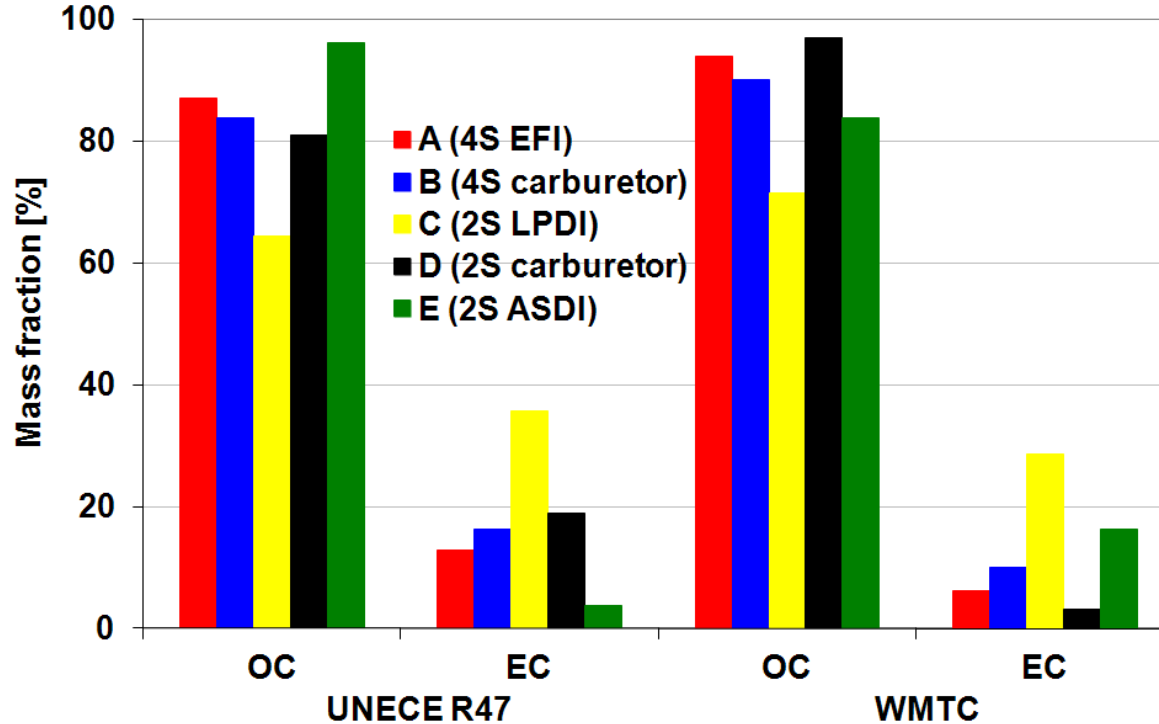
- Proposed Euro 5 includes PM limit of 4.5 mg/km.
- Only 4-stroke EFI able to meet requirement (with safety margin).
- Other vehicles between 5 and 12 mg/km.

# Particle Number

- Range from  $3 \times 10^{12}/\text{km}$  to  $3 \times 10^{14}/\text{km}$ .
- Both 2- and 4-stroke mopeds showed similar PM number levels to diesel cars not equipped with Diesel Particulate Filters.
- First acceleration accounts for most of particles number (cold start enrichment).
- Test cycle independent .



# Particulates Composition



- Organic and Elemental Carbon fractions of collected soot.
- Very little EC despite high PM numbers.
- PM emitted by 4-stroke mopeds is largely OC
- OC > 80% for most mopeds (except 2-stroke LPDI) – comes from lube oil or fuel.

# Conclusions

- Emissions levels mainly depend on quality of air-fuel mixture preparation and interaction with aftertreatment.
- Technologies are available to permit 2-stroke engines to meet proposed Euro 3 limits.
- Proper AF control is pre-requisite for effective application of catalysts to 4-stroke mopeds.
- Cold start has a major influence on gaseous and particles emissions.
- Only the 4-stroke EFI machine would have met the proposed PM limit for Euro 5.
- Solid (PMP) particle number emissions are at a similar level to diesel cars without DPF.



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- ⊙ AECC
- ⊙ Air Quality & Health Effects
- ⊙ Emissions Legislation
- ⊙ Engine & Vehicle Emissions
- ⊙ Technology
- ⊙ Applications
- ⊙ Conservation
- ⊙ Newsletter
- ⊙ Publications

### Who are AECC and what do we do ?

**AECC** is an international non-profit scientific association of European companies making technologies for engine exhaust emissions control.

The members of AECC are companies operating worldwide in the research, development, testing and manufacture of key technologies for emissions control.

Their products are the ceramic and metallic substrates for catalysts and filters; autocatalysts (substrates with catalytic materials incorporated or coated); adsorbers; filter-based technologies to control particulate emissions from diesel and other lean burn engines; and speciality materials incorporated into the catalytic converter or filter.

Catalyst-equipped cars were first introduced in the USA in 1974 but only appeared on European roads in 1985 and in 1993 legislation forced their use on cars. Now more than 275 million of the world's 500 million cars and over 85% of all new cars produced worldwide are equipped with autocatalysts. Catalytic converters and filters are also fitted to heavy-duty vehicles, motorcycles and non-road engines and

### What are the emission control technologies?

Exhaust gas contains carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx) and particulate matter (PM). The main technologies used to treat exhaust to remove harmful gases and particles are:

- autocatalysts
- adsorbers (traps)
- filters

There are more details on the technology pages.



# Thank you for your attention

Dieselretrofit