



LABORATORY OF APPLIED THERMODYNAMICS

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# **Study on possible new measures concerning motorcycle emissions**

**Particle Emissions of 2-Stroke Scooters  
11-12 June 2009, Monza, Italy**

## Background

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Based on the:

*“Study on possible measures concerning motorcycle emissions”*

Financed by the European Commission – DG-ENTR

*(8th service request under framework service contract ENTR/05/18)*

Total budget: 78500 €







*The opinions expressed by the authors of this presentation do not represent the Commission’s official position*

## Targets of the study discussed in this presentation







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- Reassess the earlier proposals made on:
  - ◆ Durability
  - ◆ In-use conformity
  - ◆ CO2 emissions and fuel consumption
  - ◆ New set of pollutant emission limit values for 3/4-cycles
  - ◆ Moped emission limits
  - ◆ OBD systems
  - ◆ Evaporation emissions
- Examine possibility to control motorcycles at Euro 5-  
"equivalent" emission standards
- Examine state-of-the art technology to reduce emissions







## Vehicle Categories Covered (Regulation 2002/24/EC) – 1(2)

Category	Vehicle Name	No of Wheels	Max Speed (km/h)	ICE Max Capacity (cm <sup>3</sup> )	ICE Max Power (kW)	Elec Motor Power (kW)	Max Unladen Mass (kg)	Characteristic Vehicles	
L1e	Moped	2	45	50		4			
L2e	Three-Wheel Moped	3	45	50 (SI)	4 (other ICE)	4			
L3e	Motorcycle	2	>45	>50					
L4e	Motorcycle+ Side Car	3	>45	>50					

## Vehicle Categories Covered (Regulation 2002/24/EC) – 2

Category	Vehicle Name	No of Wheels	Max Speed (km/h)	ICE Max Capacity (cm <sup>3</sup> )	ICE Max Power (kW)	Elec Motor Power (kW)	Max Unladen Mass (kg)	Characteristic Vehicles	
L5e	Motor Tricycles	3 (symmetrical)	>45	>50					
L6e	Light Quadricycles	4	45	50 (SI)	4 (other ICE)	4	350		
L7e	Heavy Quadricycles	4			15	15	400 (passengers) 550 (goods)		

# Vehicle Categories NOT Covered by Regulation 2002/24/EC

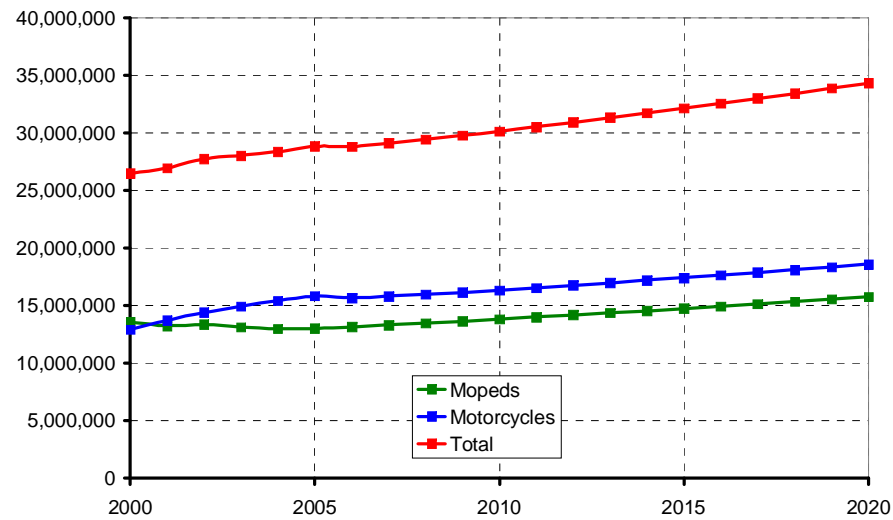
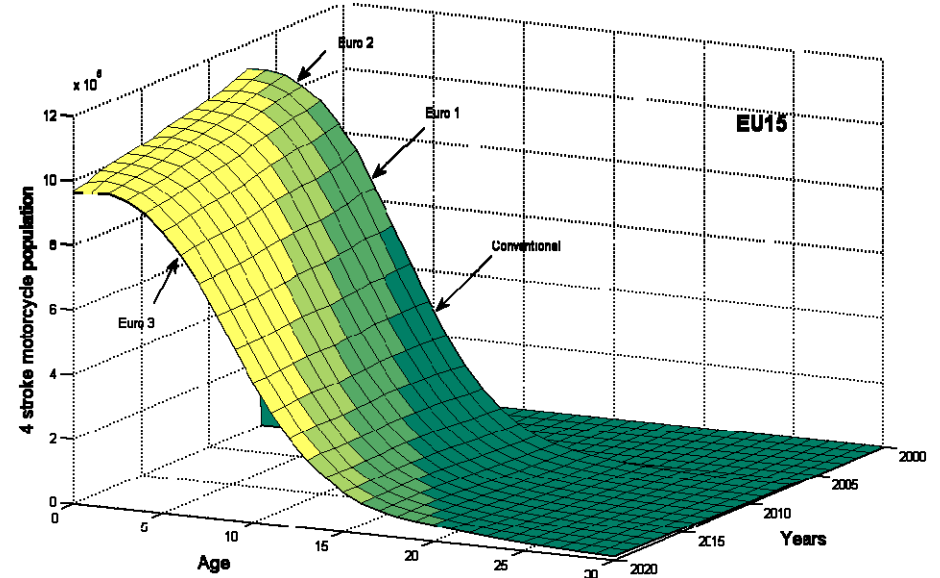
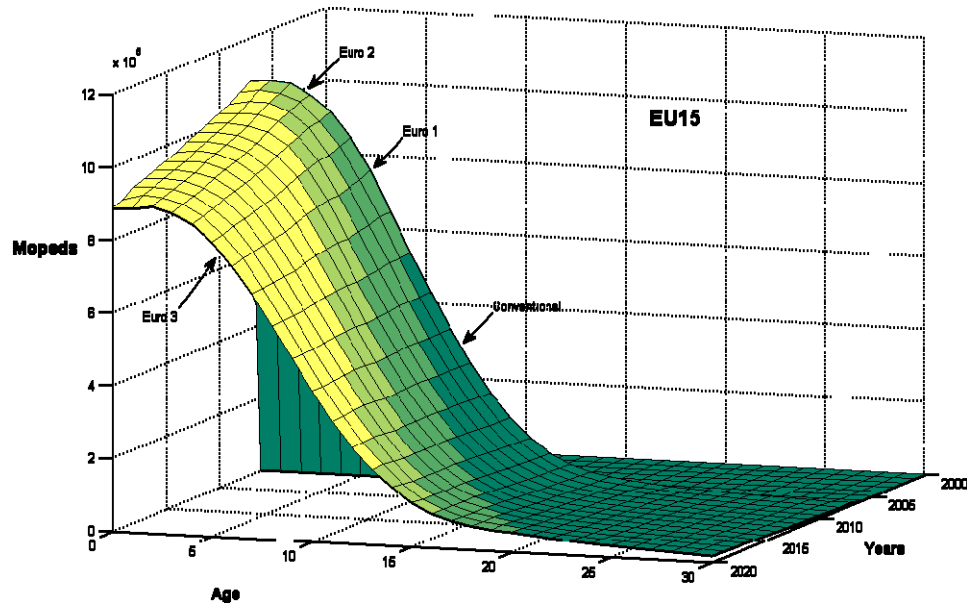
Speed less than 6 km/h	
For the physically handicapped	
Used for Competition	
Tractors and Machines used for agricultural or similar purposes	
Electric Bicycles	
Vehicles designed primarily for off-road leisure use having wheels arranged symmetrically with one wheel at the front of the vehicle and two at the rear	

## Fleet Evolution/Projection

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- Current (2005) Fleets:
  - ◆ PTWs: Results from the FLEETS (DG ENV) project on vehicle stocks in all European countries
  - ◆ Other categories: Tremove V2.52
  
- Projections
  - ◆ TREMOVE model (V2.52) scaled to PTW FLEETS data
    - Motorcycle population and corresponding age distributions
    - EU15 member states
    - Euro 5/6: Included
    - Euro VI: Scenario G5/A1 included  
(NOx: 0,4 g/kWh, PM: 0,01 g/kWh, 50% cost allocation, Including AdBlue costs)
  
- Tri, quadricycles:
  - ◆ All ATVs assumed gasoline vehicles, 5-year lifetime, 3Mm per year
  - ◆ All quadricycles (mini-cars) assumed diesel, 12-year lifetime, 6Mm per year
  - ◆ Population assumes PTW increase for post 2008 values

# PTW Population (EU15)

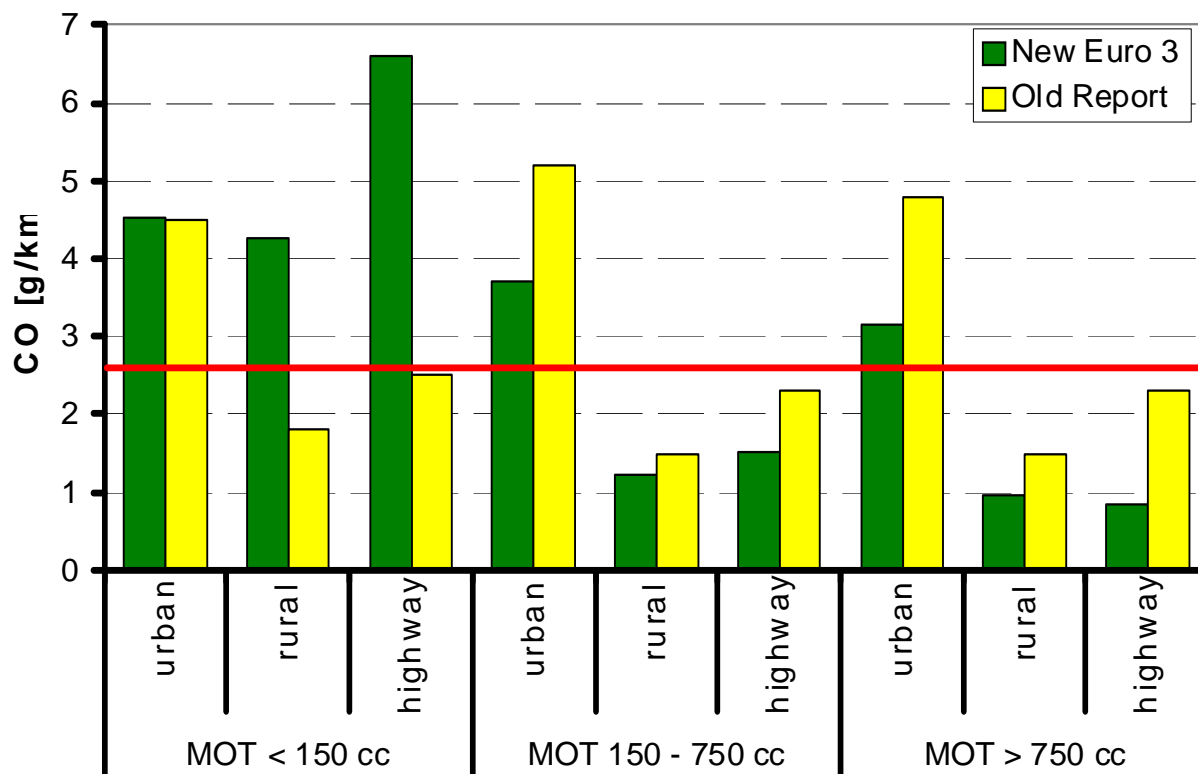


## Emission factors (EF)

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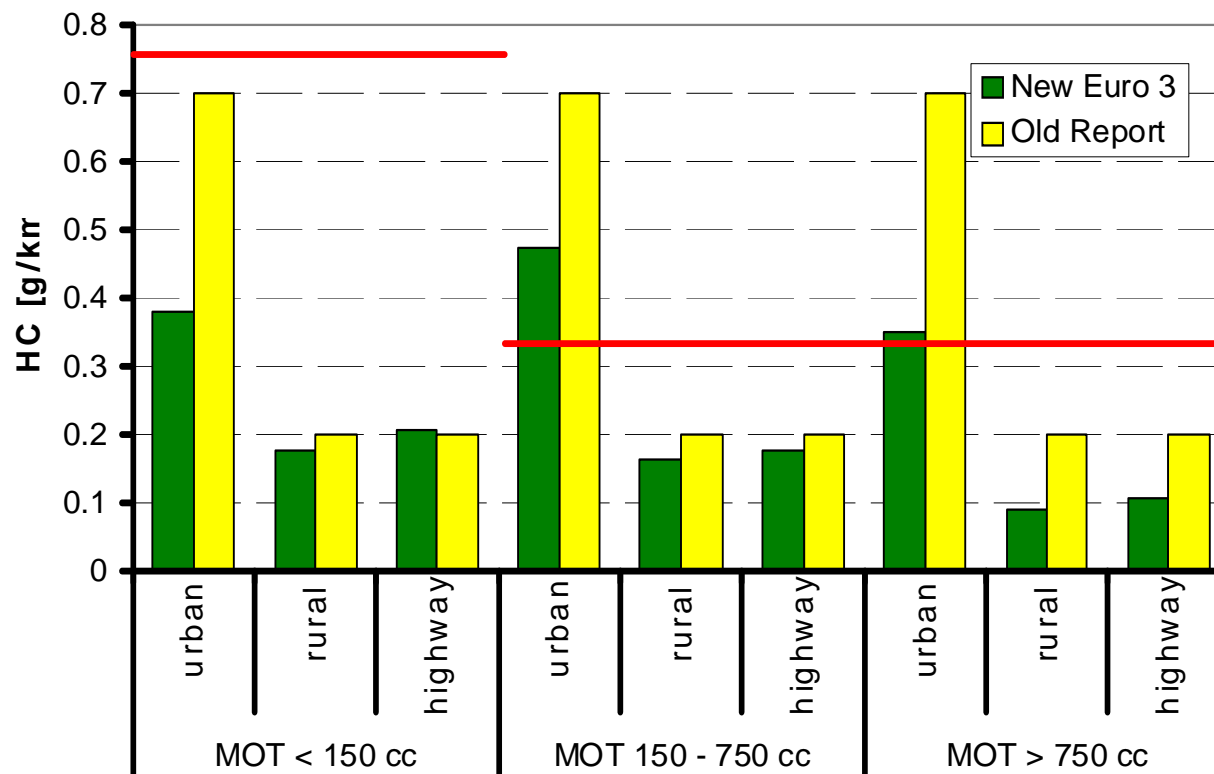
- UNECE WMTC Correlation Database
- Pre Euro 3 PTWs and Euro 3 mopeds EFs
  - ◆ Emission factors developed in the ARTEMIS project on the basis of experimental information
- New Euro 3 EFs
  - ◆ Measurements on 15 vehicles from EMPA and AECC
  - ◆ Three distinct EFs were derived based on the 3 WMTC phases
    - Urban EF → WMTC phase 1
    - Rural EF → WMTC phase 2
    - Highway EF → WMTC phase 3

## CO Emission Factors



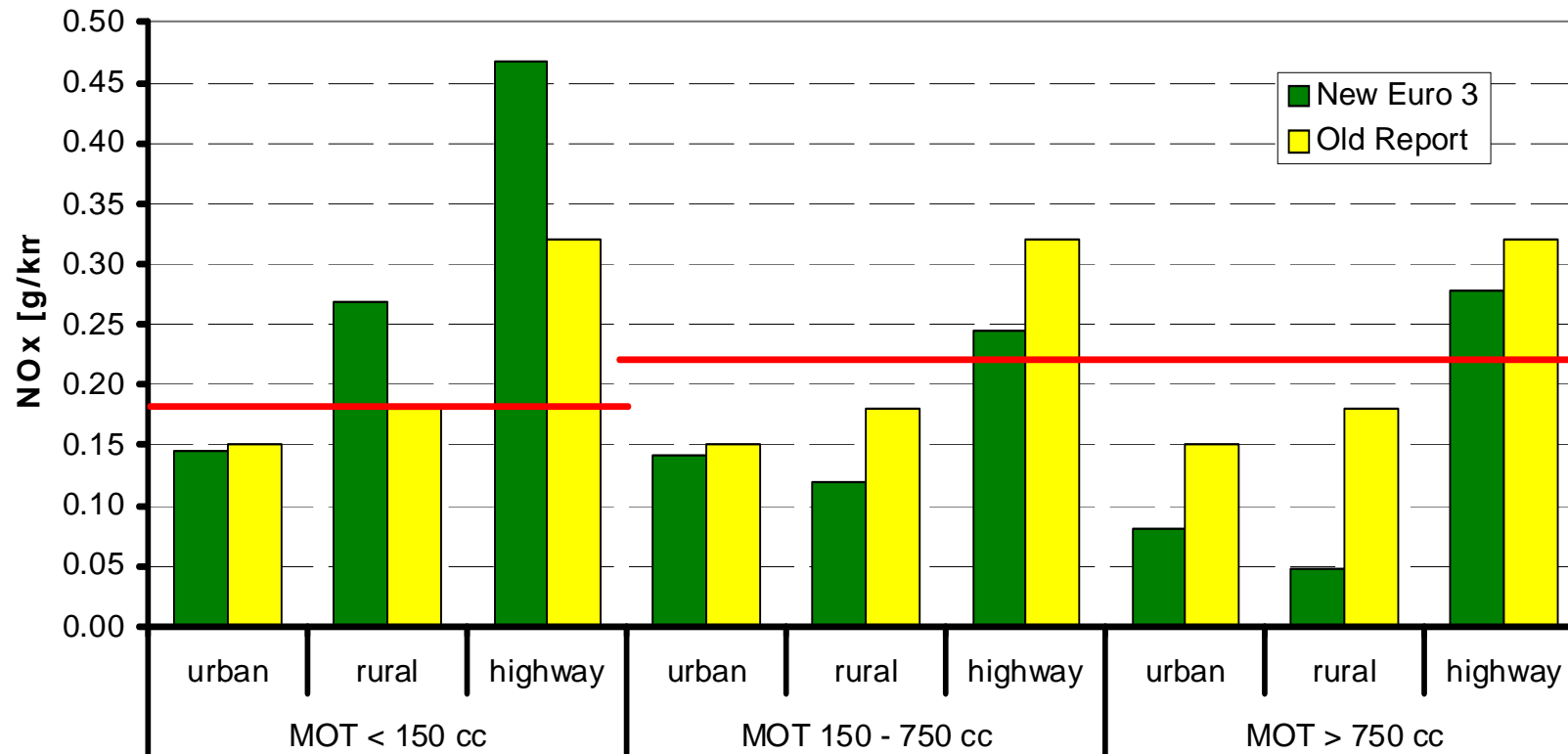
- Significant deviations only for the small class
- It is counterbalanced by opposite trends in larger motorcycles
- WMTC seems demanding for small motorcycles

## HC Emission Factors



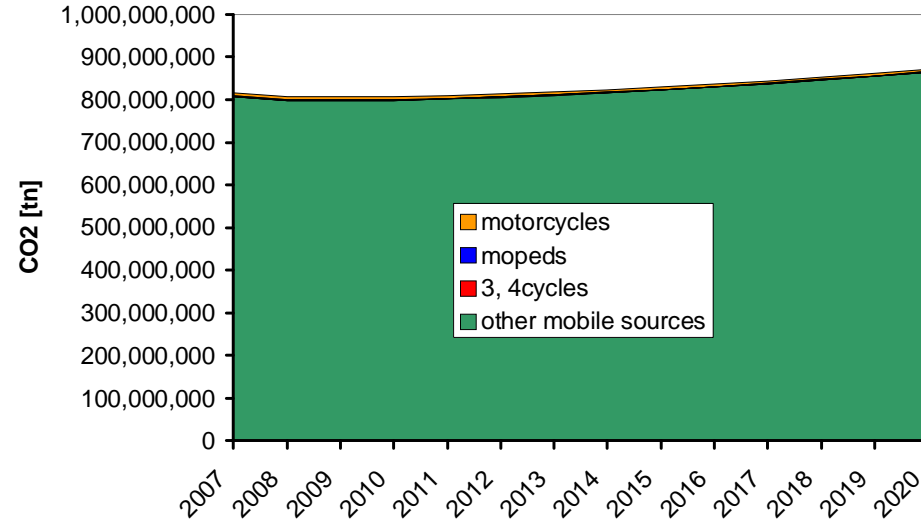
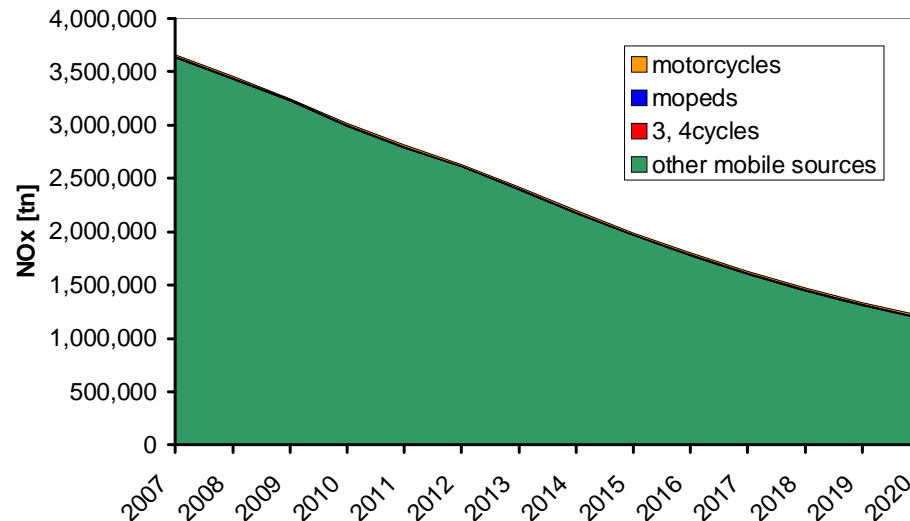
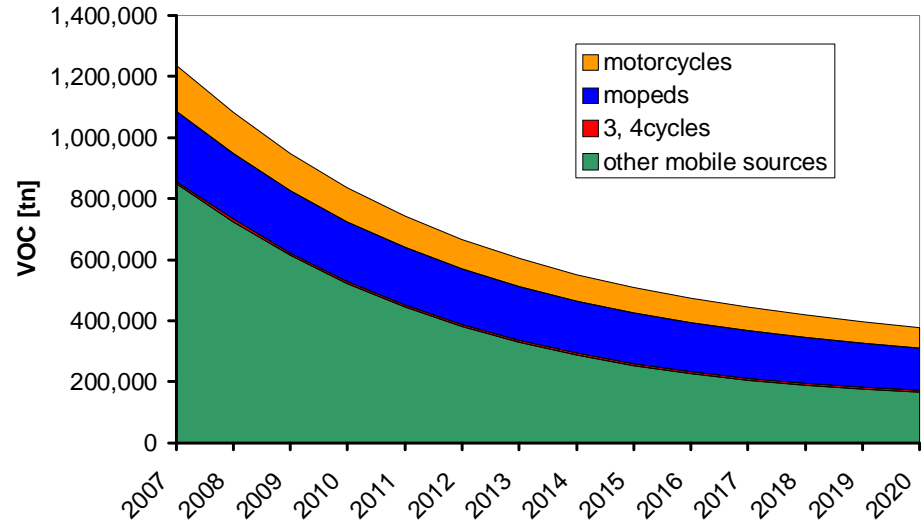
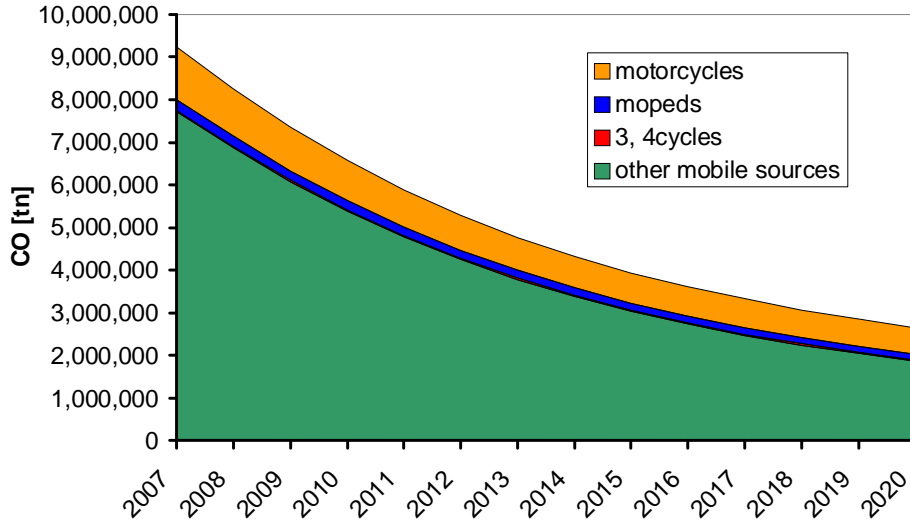
- Significant overestimation of the urban part by the old report
- No particular issue in meeting the HC emission standard

## NOx Emission Factors



- Higher NOx emissions from small motorcycles than earlier predicted for small motorcycles
- Much better performance by large motorcycles

# Contribution of PTW to total mobile sources emissions (TREMOVE 2.52 data)



## Policies Considered

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- Policy 1: No policy change (Directives 2002/51/EC & 2006/72/EC)
  - ◆ Euro 3 motorcycles
  - ◆ Euro 2 mopeds
  
- Policy 2: Initial Commission Proposal
  - ◆ *According to "Status Report Emissions" File*
  
- Policy 3: Euro 5 Passenger Cars equivalent limits (2010)
  - ◆ Euro 5 PC / Euro 3 PC reductions
  
- Policy 4: Best Available Technology (2010)
  - ◆ Chosen among the best performing late model PTWs within the available measurements

# Policy options

	No policy change	Commission proposal	Euro 5 passenger cars equivalent limits	Best available technology
	<i>No additional measures beyond 2006/72/EC</i>	<i>Moto 105 (Corrected for Nov 23 Report)</i>	<i>Baseline scenario with the introduction of more stringent emission limits equivalent to the Euro 5 limits for passenger cars</i>	<i>Application of the "best available technology" for two and three-wheel motor vehicles</i>
<b>Emission limits</b>	No introduction of a Euro 3 stage for mopeds	Euro 3 for mopeds, updated Euro 3 motorcycle emission factors	Equivalency based on Euro 5 over Euro 3 PC reductions, cycle corrected for motorcycles only	Best available technology for motorcycles and mopeds
<b>New technologies examined</b>	Smaller capacity two-stroke engines: two-stage oxidation catalysts with secondary air injection, pre-cat and Direct Injection combustion Larger four-stroke motorcycles: three-way catalytic converters with closed loop lambda control Electronically controlled fuel injection system		Further optimised fuel injection, <a href="#">variable valve timing</a> , <a href="#">variable cylinder management</a> , <a href="#">multi-map engine control</a> , <a href="#">friction reduction inside the engine</a> , <a href="#">lean burn technology</a> , improved catalyst with earlier activation to reduce cold start emissions, improved O <sub>2</sub> -sensors to reduce the fluctuations of the air/fuel ratio	
<b>Durability of emission control systems</b>	No durability requirements	ACEM proposal (Moto 69)	Durability requirements based on equivalent to PC lifetime distances (160 Mm)	N/A
<b>In-use compliance of motorcycles</b>	No in-use compliance requirement	No proposal	IUC on all motorcycle models	N/A
<b>Technical provisions for the type-approval with respect to CO<sub>2</sub> emissions and fuel consumption</b>	No CO <sub>2</sub> /Fuel consumption measurement	CO <sub>2</sub> /Fuel consumption measurement procedure	CO <sub>2</sub> /Fuel consumption measurement procedure/Labelling	
<b>The new set of pollutant emission limit values for tricycles and quadricycles discussed in the MVEG group</b>	Baseline emission factors	Revised emission factors based on the ECE40 (account for Moto 57)	Equivalency based on Euro 5 over Euro 3 PC reductions	Best available technology (using ECE40)
<b>OBD systems</b>	No OBD requirement	No OBD requirement	EOBD in all models incl. equivalent thresholds	Circuit integrity monitoring
<b>Control of evaporative emissions</b>	No evaporative emissions control legislation	Evaporative emissions control requirement (Moto 107)	Evaporative emissions control using the PC procedure	
<b>Introduction of the WMTC</b>	Old GTR2 optional		New GTR2 mandatory	

## Emission factors for scenarios

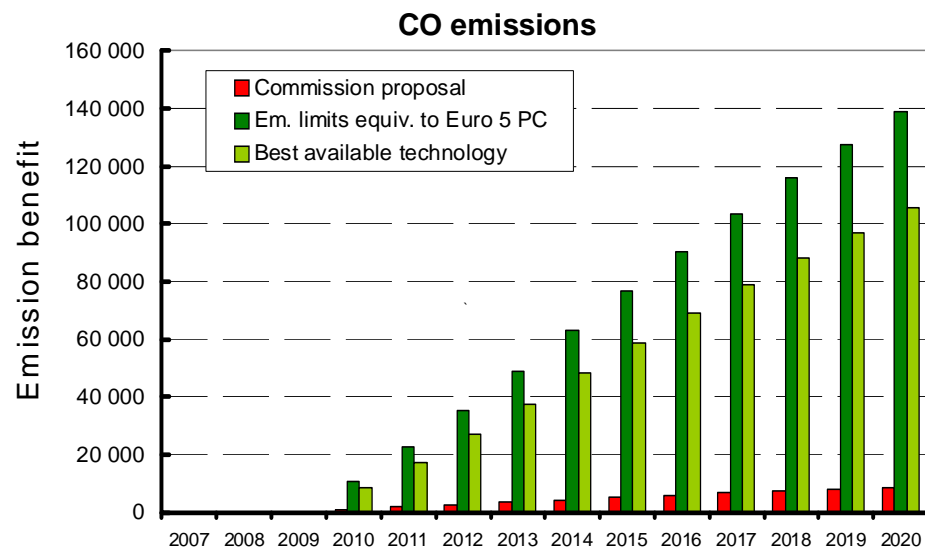
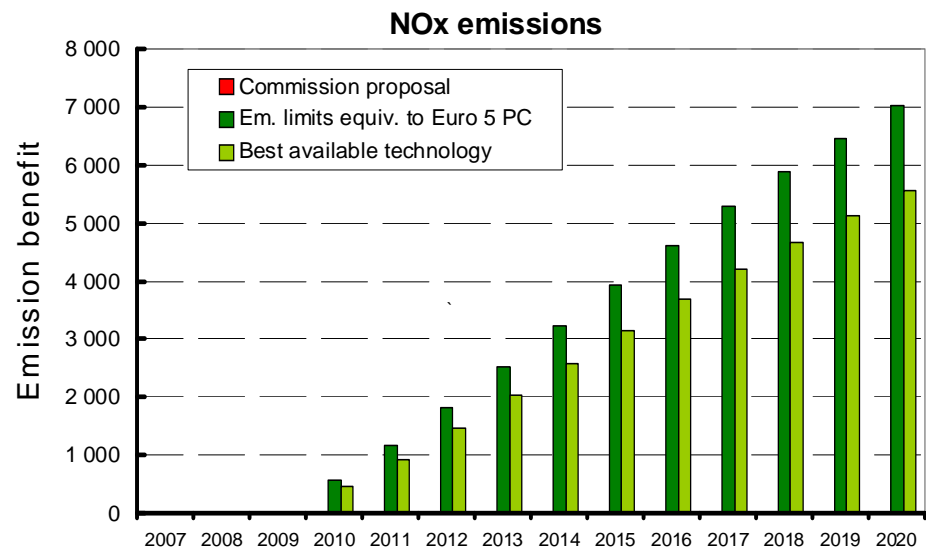
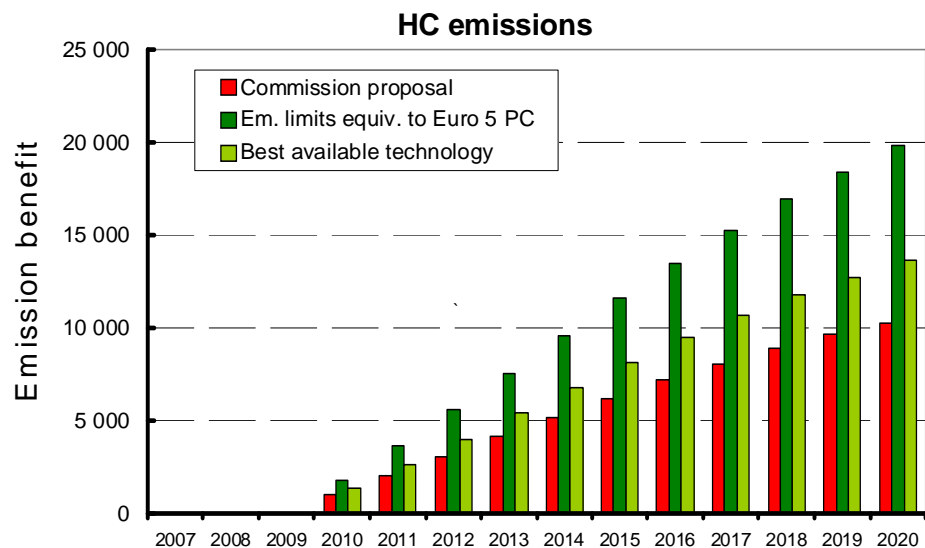
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- Initial Commission proposal:
  - ◆ Euro 3 for mopeds (30% cold start) (2010)
- Euro 5 equivalent EFs (2010)
  - ◆ estimated based on the reduction of the Euro 5 over Euro 3 passenger car limits:

$$EF_{PTW, eq.to EURO 5 PC} = EF_{PTW, EURO 3} \times \frac{[Euro 5 PC Emission Limit]}{[Euro 3 PC Emission Limit]}$$

- Best available technology (2010):
  - ◆ chosen as the 20<sup>th</sup> percentile of the best performing modern motorcycles within the available measurement dataset

# Emission benefit from motorcycle new emission limits



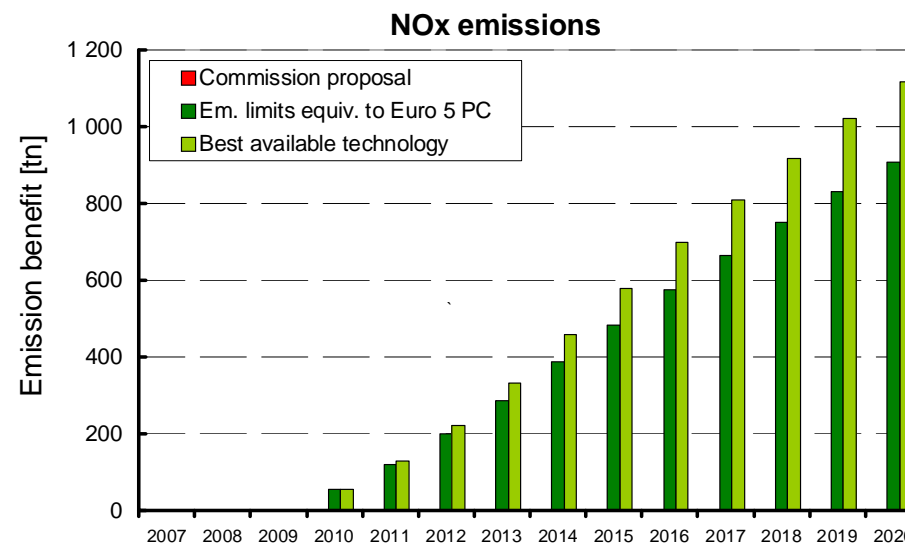
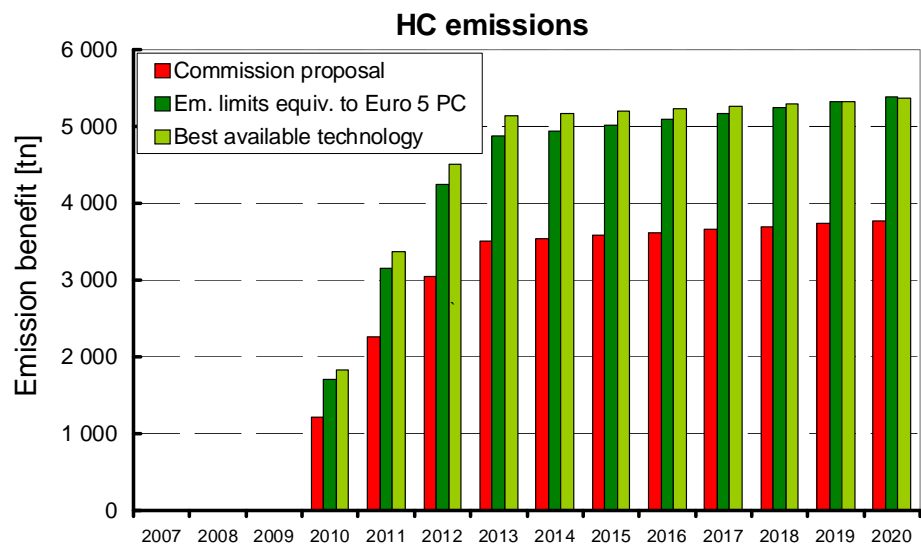
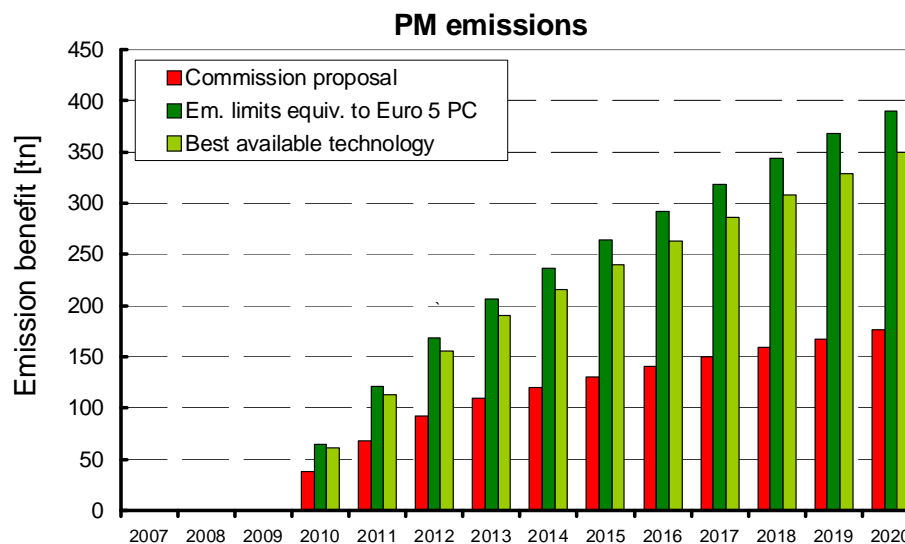
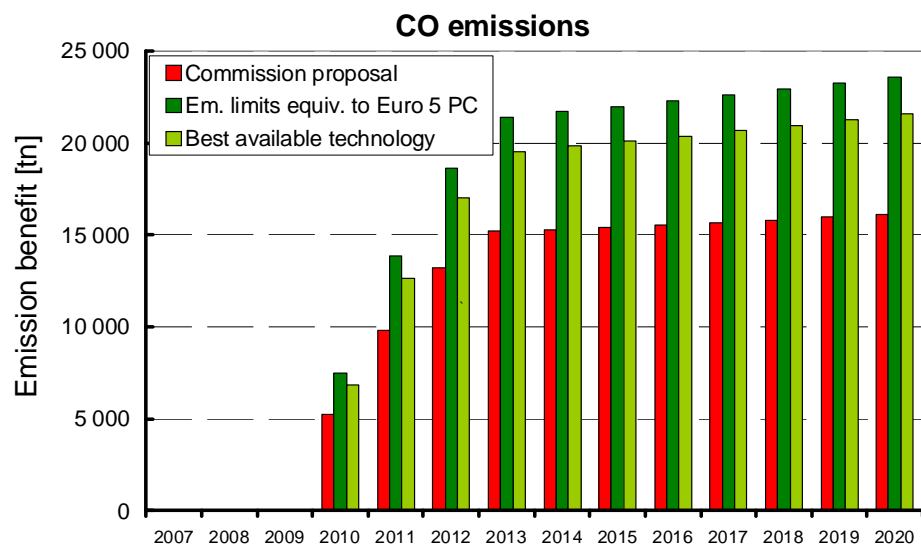
## Tri, quadricycles scenario assumptions

- Only urban and rural driving
- New technology assumed to be introduced in 2010 over Euro 2
- Commission proposal:
  - ◆ Euro 3 for tri and quadricycles according to “moto 105” in 2010

Limit values for tricycles and quadricycles for type approval and conformity of production (positive ignition)-					
Appendix 1a	All	4,0	1,0	0,25	-
Limit values for tricycles and quadricycles for type approval and conformity of production (compression ignition)					
Appendix 1a	All	1,0	0,15	0,65	0,1

- Euro 5 PC equivalent:
  - ◆ Petrol: Euro 5 petrol PC equiv. (E5/E3) emission std. for CO, HC, NOx, PM
  - ◆ Diesel: Euro 5 diesel PC emission std. for CO, HC, NOx, PM
- Best available technology:
  - ◆ Petrol: Emissions equal to Euro 3 500 cc PTW for CO, HC, NOx
  - ◆ Diesel: Euro 4 diesel PC emission std. for CO, HC, NOx, PM

# Benefit from tri, quadricycle new emission limits

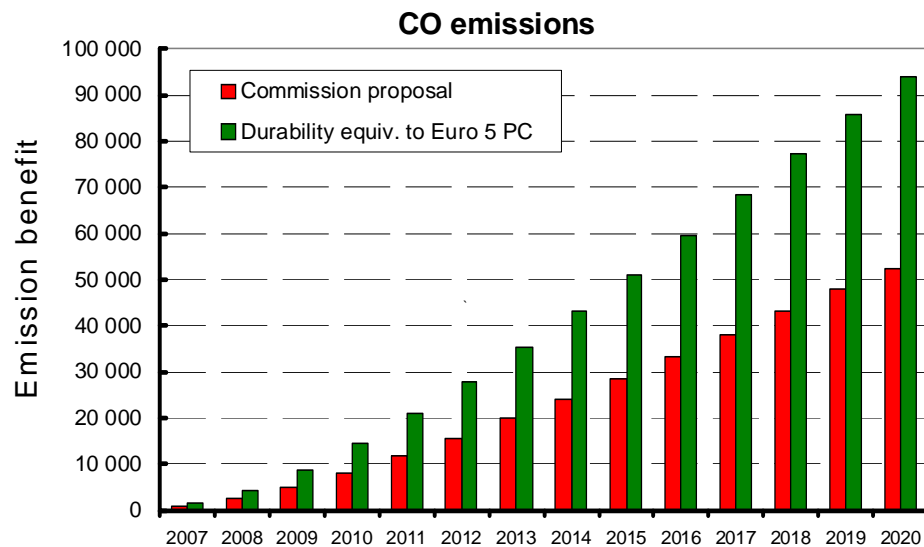
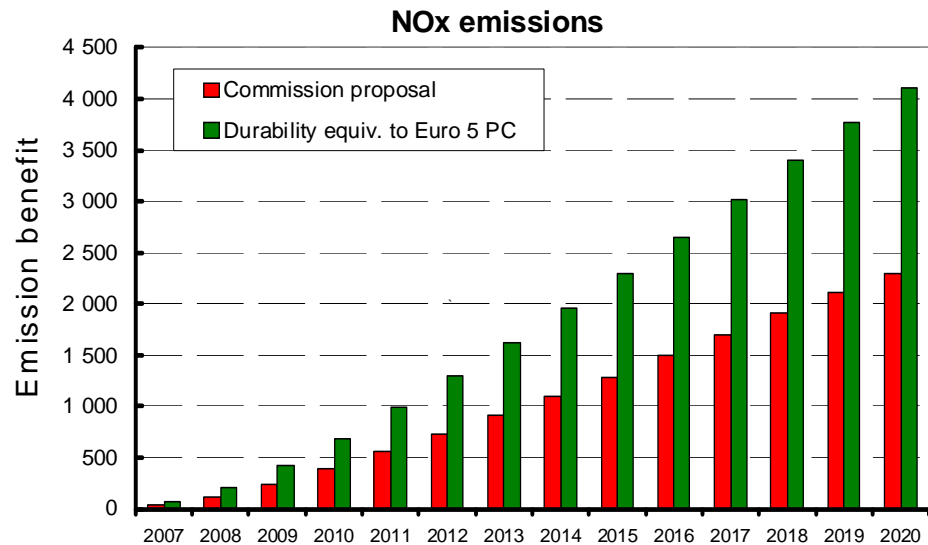
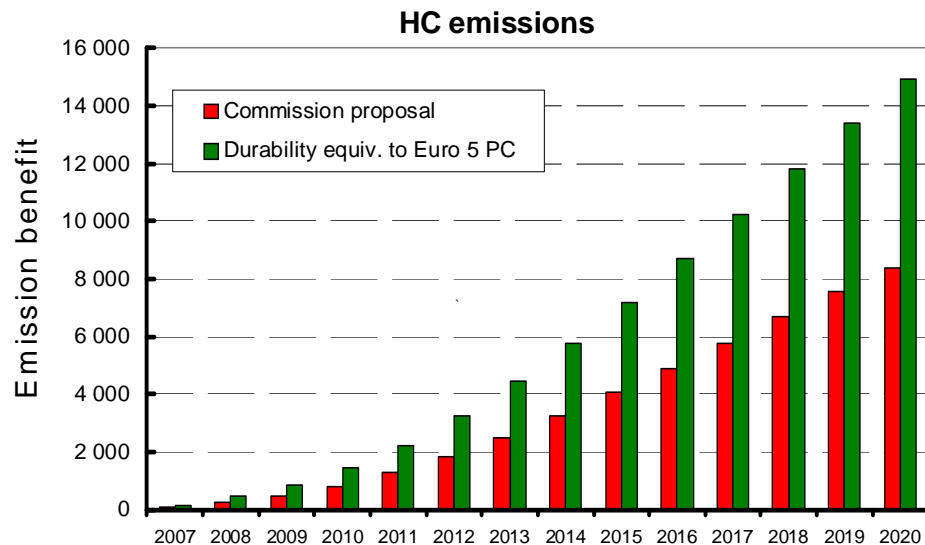


## Durability scenarios

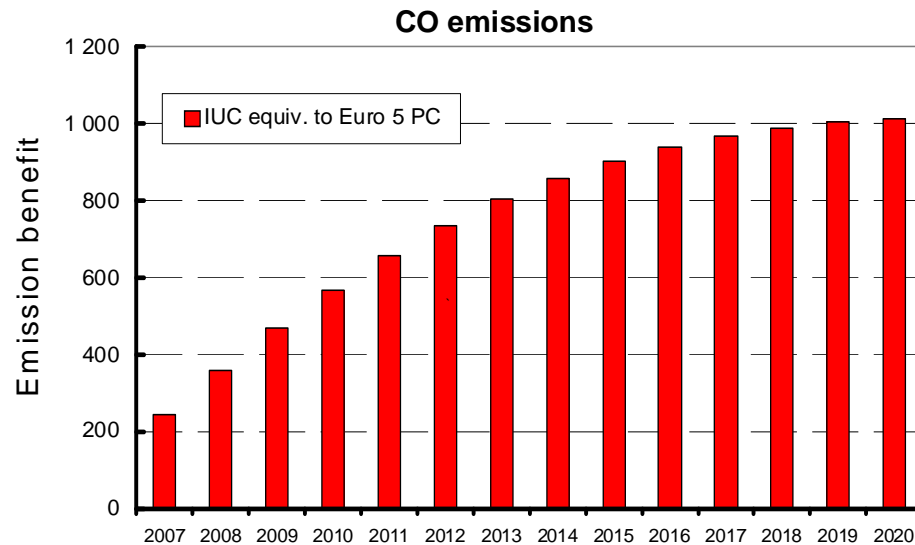
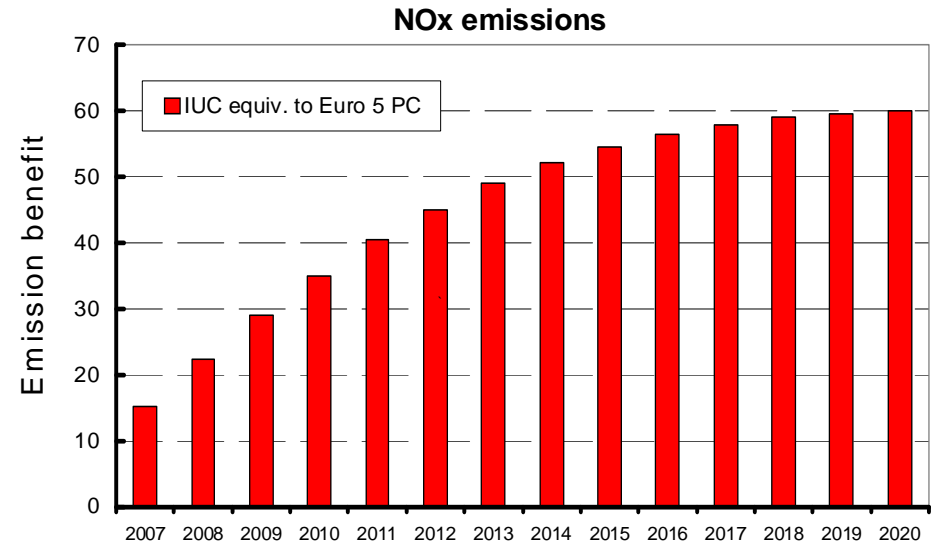
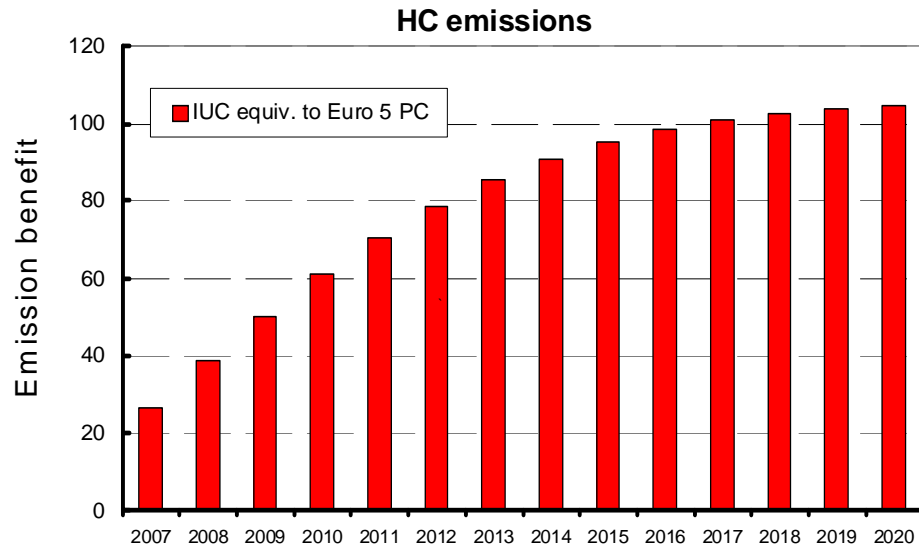
		Basecase	Commis. proposal	Euro 5 equival.
<b>Deterioration per useful life</b>	Conventional	20%		
	Euro 1	20%		
	Euro 2	20%		
	Euro 3	20%	10%	10%
<b>useful life [km]</b>	Mopeds	10000		44000
	Mot 2 str	12000		68000
	Mot 4 str <150 cc	12000		74000
	Mot 4 str 150 - 750 cc	30000		74000
	Mot 4 str > 750 cc	30000		74000

- Commission proposal:
  - ◆ Deterioration reduced to 10% (linear extrapolation for higher mileage)
- Euro 5 PC equivalent:
  - ◆ Useful life increased based on the PC value (160Mm) converted to PTW equivalent by the ratio of the annual mileage of PTW over the annual mileage of PCs (estimated per EU country)

# Durability scenarios



# In-use compliance scenarios



- Euro 5 PC equivalent:
  - ◆ IUC for all Euro 3 motorcycles

## On-Board Diagnostics scenarios

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➤ Euro 5 PC equivalent:

- ◆ Application of OBD systems similar to PCs (EOBD), including catalyst efficiency monitoring

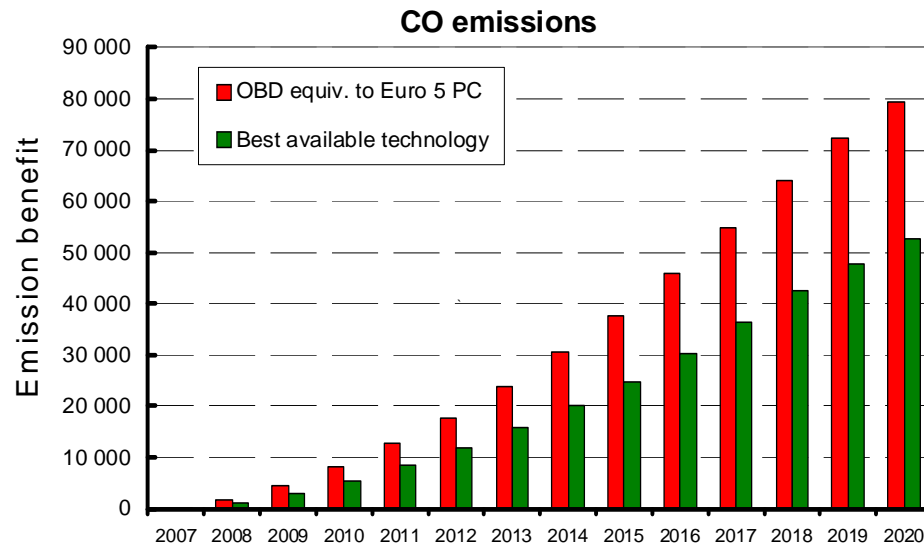
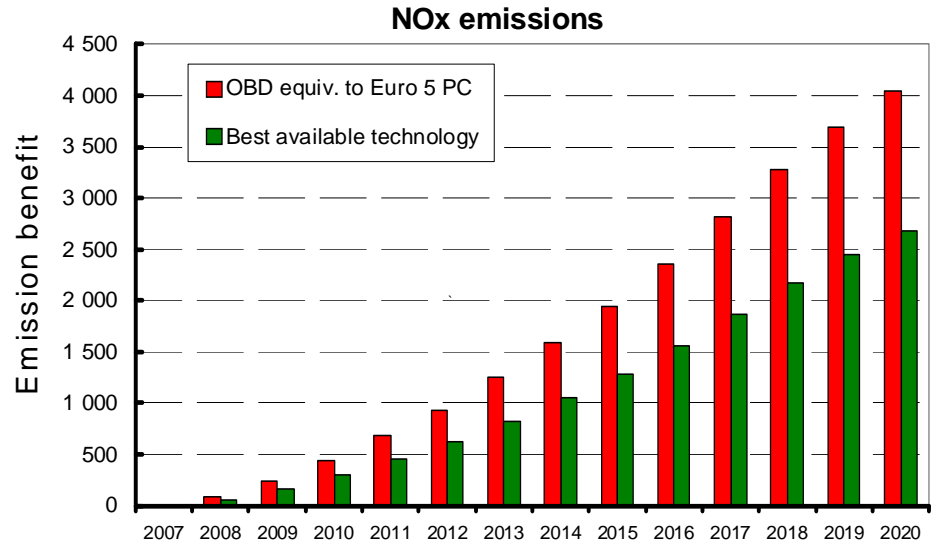
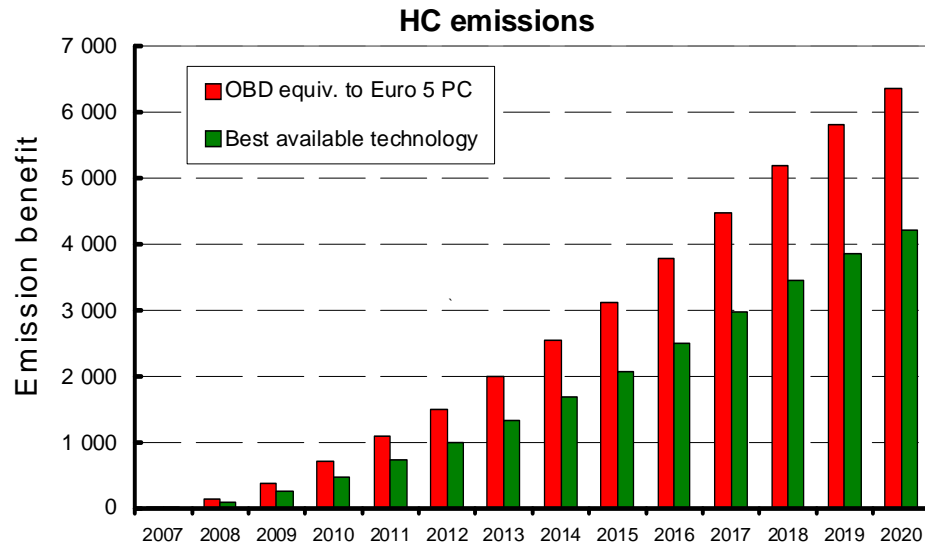
➤ Best available technology (BAT):

- ◆ Minor malfunction monitoring (e.g. circuit integrity check) (OBD1)

Note:

In both scenarios, the maximum potential is evaluated, i.e. the diagnosis occurs instantly and the malfunction repair is immediate

# On-Board Diagnostics scenarios



## Current status of PTW emissions 1(2)

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### ➤ **NOx emissions**

- ◆ motorcycles responsible for 0.5% of total NOx road transport emissions
- ◆ mopeds responsible for 0.2% of total NOx road transport emissions

### ➤ **PM emissions**

- ◆ motorcycles responsible for 1% of total PM road transport emissions
- ◆ mopeds responsible for 1.7% of total PM road transport emissions

## Current status of PTW emissions 2(2)

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### ➤ **HC emissions (including evaporation)**

- ◆ mopeds responsible for 20% of total HC road transport emissions
- ◆ motorcycles responsible for 13% of total HC road transport emissions
- ◆ small PTWs are responsible for a large share of urban HC emissions

### ➤ **CO emissions**

- ◆ mopeds are responsible for another 4% of total
- ◆ motorcycles are responsible for 12% of total road transport emissions

## Future evolution of PTW emissions 1 (2)

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### ➤ **NOx emission contribution**

- ◆ will continue to increase rather exponentially
- ◆ in 2020, it is expected that mopeds and motorcycles combined will be responsible for 2% of total road transport emissions
- ◆ the share of PTWs will increase but stabilize at less than 8%

### ➤ **PM emission contribution**

- ◆ as diesel particle filters appear for cars and trucks, the share of PTWs increase again and reaching some 5% of total PM emissions
- ◆ more than 35% will come from quadricycles and, in principle, diesel mini-cars

## Future evolution of PTW emissions 2(2)

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### ➤ **HC emission contribution**

- ◆ will continue to increase in the future - it is projected to exceed 50% of total road transport emissions by 2020
- ◆ an efficient policy is therefore necessitated to further control emissions of, primarily mopeds, and motorcycles

### ➤ **CO emission contribution**

- ◆ will also increase and PTWs are projected to contribute to some 30% of total CO by 2020
- ◆ although not a priority pollutant in Europe, more strict control would be required to control the contribution of PTW to current levels

## Additional measures

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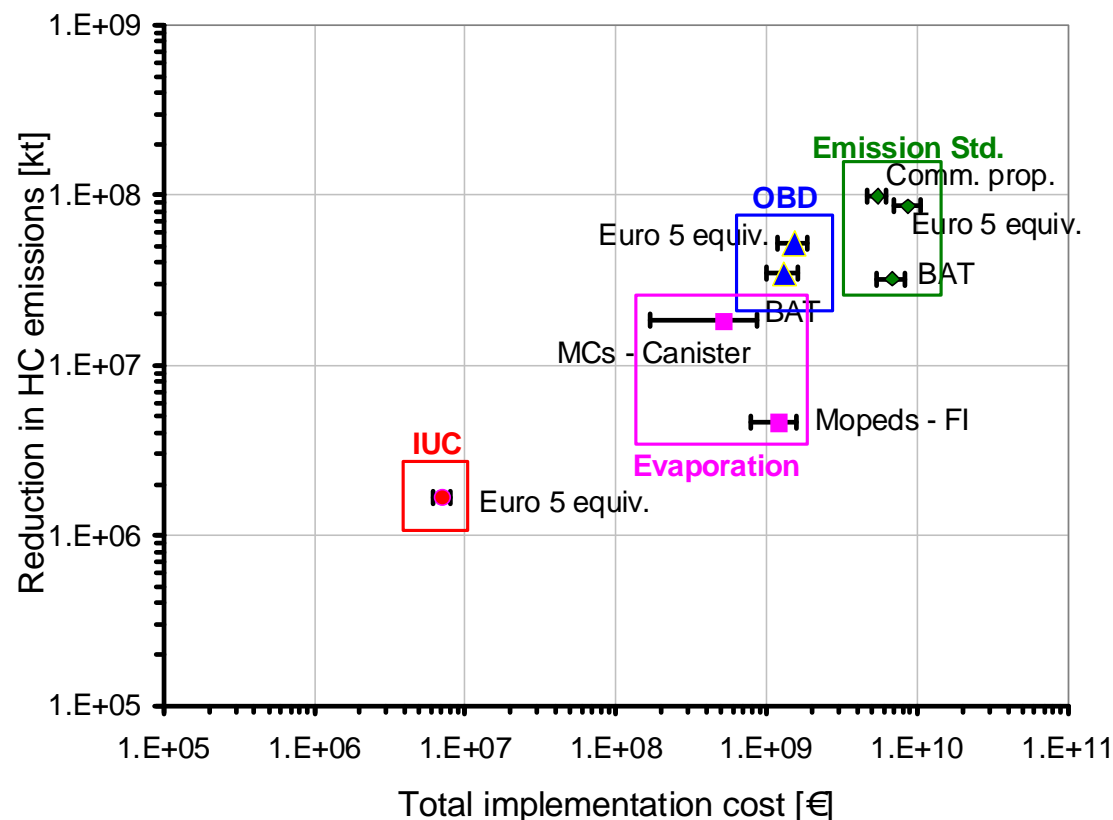
### ➤ **Regulations for durability**

- ◆ need to be introduced to control emissions over the useful life of the vehicle
- ◆ certain models may emit much beyond the emission limits at relatively short mileage after their type-approval
- ◆ the actual distance used as a useful life is of secondary importance

### ➤ **Periodic road-worthiness test**

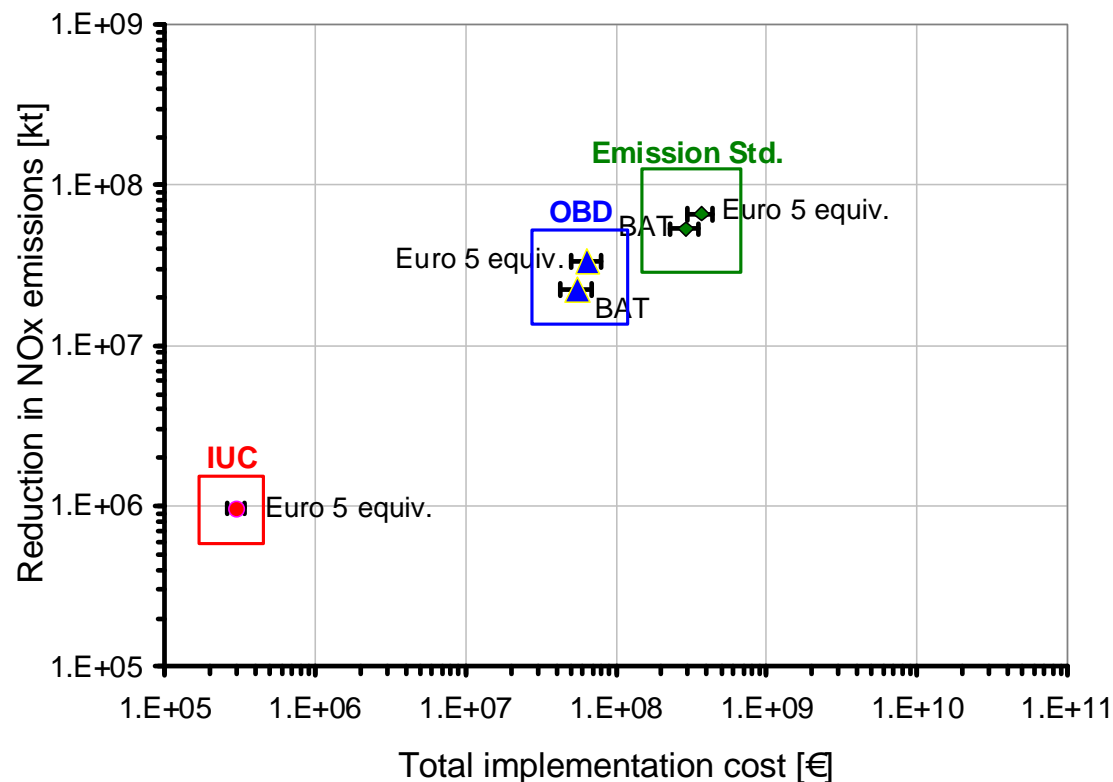
- ◆ very suitable measure in controlling emissions from motorcycles (not reassessed in current study)

## Overall evaluation of options - HC



- **In Use Compliance:** both low cost and a low effectiveness measure
- **Evaporation control:** most cost-effective solution
- **Euro 3 for mopeds:** most effective solution
- **OBD measures:** more cost-effective than the BAT for MC em. control

## Overall evaluation of options - NOx



- **In Use Compliance:** both low cost and low effectiveness measure
- **OBD options:** more costly and more effective
- **Tightening of the em. standards:** highest effectiveness, highest cost

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**Thank you for your attention**

