Measurements of exhaust gas emission of light vehicles

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L-vehicles Emissions and Noise mitigation Solutions

Overview and Background

Explanation of L-Category Vehicles

- What do L-Category vehicles cover?
  - Not only two-wheelers are eligible for L-Category

Category	LV Sub Category	
L1e	L1e-B - Two-Wheel moped	
L2e	L2e-P - 3-wheel moped for passenger transport	
	L2e-U - 3-wheel moped for utility purposes	
L3e & L4e	L3e-A1 - Low-performance motorcycle	
	L3e-A2 - Medium-performance motorcycle	
	L3e-A3 - High-performance motorcycle	
	L3e-AxE - Enduro motorcycles	

Category	LV Sub Category	
L5e	L5e-A - Tricycle	
	L5e-B - Commercial tricycle	
L6e	L6e-A - Light on-road quad	
	L6e-B - Light quadri-mobile	 BP
L7e	L7e-B1 - All terrain quad	
	L7e-B2 - Side By Side Buggy	

Source: R(EU) 168/2013, (european-union.europa.eu)

L-vehicles Emissions and Noise mitigation Solutions

Explanation of L-Category Vehicles

- L-Category classes

Category	Category name	Vehicle classification criteria

L1e-A/B	Light two-wheel powered vehicle	➢ Two wheels
		➢ Engine capacity ≤ 50 cm³ if SI engine type
		➢ Both 2 and 4-Stroke engines
		➢ Maximum designed vehicle speed ≤ 45 km/h
		➢ Maximum continuous rated or net power ≤ 4 kW
		➢ L1e-A – Powerewd cycle
		  ➢ Cycles designed to pedal
		  ➢ Maximum designed vehicle speed ≤ 25 km/h
		  ➢ Maximum continuous rated or net power ≤ 1 kW
		➢ L1e-B – Two-wheel mopped
		  ➢ Any other vehicle of L1e that cannot be classified as L1e-A

L2e	Three-wheel moped	➢ Three wheels ➢ Engine capacity ≤ 50 cm³ if SI engine or ≤ 500 cm³ if CI engine ➢ Both 2 and 4-Stroke engines ➢ Maximum designed vehicle speed ≤ 45 km/h ➢ Maximum continuous rated or net power ≤ 4 kW ➢ Mass in running order ≤ 270 kg ➢ Maximum of two seating positions

Source: R(EU) 168/2013, (european-union.europa.eu)

L-vehicles Emissions and Noise mitigation Solutions

Explanation of L-Category Vehicles

- L-Category classes

Category	Category name	Vehicle classification criteria
L3e-A1	Low-performance motorcycle	➢ Two-wheels, without side-car and cannot be classified as a category L1e vehicle ➢ Engine capacity ≤ 125 cm³ if SI engine type ➢ Both 2 and 4-Stroke engines ➢ Maximum continuous rated or net power ≤ 11 kW ➢ Power/weight ratio ≤ 0.1 kW/kg
L3e-A2	Medium-performance motorcycle	➢ Any other L3e vehicle that cannot be classified according to the classification criteria of a L3e-A1 ➢ No limitation in engine capacity ➢ Both 2 and 4-Stroke engines ➢ Maximum continuous rated or net power ≤ 35 kW ➢ Not derived from a vehicle equipped with an engine of more than double its power (≤ 70 kW) ➢ Power/weight ratio ≤ 0.2 kW/kg
L3e-A3	High-performance motorcycle	➢ Any other L3e vehicle that cannot be classified according to the classification criteria of a L3e-A1 or L3e-A2 ➢ No limitation on engine capacity neither rated power ➢ Both 2 and 4-Stroke engines

Source: R(EU) 168/2013, (european-union.europa.eu)

L-vehicles Emissions and Noise mitigation Solutions

Explanation of L-Category Vehicles

- L-Category classes

Category	Category name	Vehicle classification criteria

L3e-AxE/T	Two-wheel motorcycle	➢ Follow L3eA categorization (x =1, 2 or 3)
		➢ T: refers to trials
		  ➢ Mass in running order ≤ 100 kg
		  ➢ Overall gear ratio in highest gear ≥ 7,5
		  ➢ No seating position for a passanger
		➢ E: refers to enduro
		  ➢ Mass in running order ≤ 140 kg
		  ➢ Overall gear ratio in highest gear ≥ 6
		  ➢ No seating position for a passanger

L4e	Two-wheel motorcycle with side-car	➢ Vehicle complying with the classification criteria for a L3e vehicle and is equipped with one side-car ➢ Maximum of four seating positions (including driver seating position) ➢ Maximum of two seating positions in the side car
L5e-A/B	Powered tricycle	➢ Three-wheels ➢ Mass in running order ≤ 1000 kg ➢ Three-wheel vehicle that cannot be classified as a category L2e vehicle ➢ L5eA: maximum five seating positions ➢ L5eB: maximum two seating positions, carriage of goods

L-vehicles Emissions and Noise mitigation Solutions

Source: R(EU) 168/2013, (european-union.europa.eu)

Explanation of L-Category Vehicles

- L1, L2, L3, L4 and L5 characteristics
  - Noticeable driver weight impact (~25-60%)
  - Air resistance is an integral part of the human/machine combination
  - High performance/engine capacity ratio

L-vehicles Emissions and Noise mitigation Solutions

Explanation of L-Category Vehicles

- L-Category classes

Category	Category name	Vehicle classification criteria
L6e-A	Light on-road quad	➢ Four wheels ➢ Maximum designed vehicle speed ≤ 45 km/h ➢ Both 2 and 4-Stroke engines ➢ Maximum continuous rated or net power ≤ 4 kW ➢ Engine capacity ≤ 50 cm³ if SI engine or ≤ 500 cm³ if CI engine ➢ Mass in running order ≤ 425 kg ➢ Maximum of two seating positions (including driver seating position)
L6e-B	Light quadri-mobile	➢ Four wheels ➢ Maximum designed vehicle speed ≤ 45 km/h ➢ Maximum continuous rated or net power ≤ 6kW ➢ Engine capacity ≤ 50 cm³ if SI engine or ≤ 500 cm³ if CI engine ➢ Mass in running order ≤ 425 kg ➢ Engine capacity ≤ 50 cm³ if SI engine or ≤ 500 cm³ if CI engine

Source: R(EU) 168/2013, (european-union.europa.eu)

L-vehicles Emissions and Noise mitigation Solutions

Explanation of L-Category Vehicles

- L-Category classes

Category	Category name	Vehicle classification criteria
L7e-A	Heavy on-road quad	➢ Four wheels ➢ Designed for transport of passengers only ➢ Maximum continuous rated or net power ≤ 15 kW ➢ Mass in running order ≤ 450 kg for transport passengers ➢ L7e vehicles that cannot be classified as a category L6e vehicle
L7e-B1	All terrain quad	➢ Four wheels ➢ Two straddle seating positions, equipped with handlebar ➢ Maximum design vehicle speed ≤ 90 km/h ➢ Mass in running order ≤ 450 kg for transport passengers or ≤ 600 kg for transport of goods ➢ L7e vehicles that cannot be classified as a category L6e vehicle
L7e-B2	Side-by-side buggy	➢ Four wheels ➢ Two side-by-side seating positions, equipped with steering wheel ➢ Maximum continuous rated or net power ≤ 15 kW ➢ Mass in running order ≤ 450 kg for transport passengers or ≤ 600 kg for transport of goods ➢ L7e vehicles that cannot be classified as a category L6e vehicle

Source: R(EU) 168/2013, (european-union.europa.eu)

L-vehicles Emissions and Noise mitigation Solutions

Explanation of L-Category Vehicles

- LVs cover a wide range of vehicle characteristics and huge variability in their usage cases

- Motorcycles for road trips

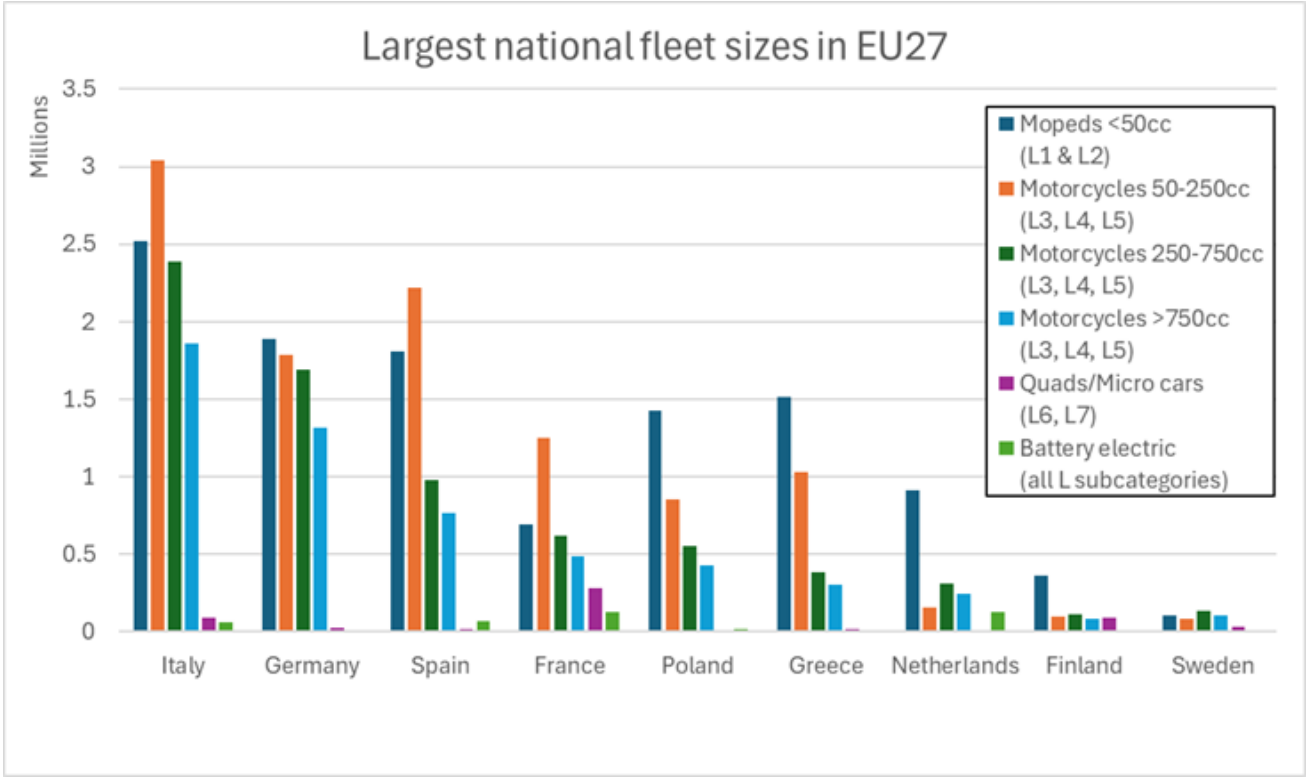
- All-terrain on-road vehicles

- Urban solely, maximum designed vehicle speed ≤ 45 km/h

L-vehicles Emissions and Noise mitigation Solutions

Explanation of L-Category Vehicles

- Usage of LVs vehicles in European regions
  - Urban mobility predominates
  - Young driver's mobility (>15 years)
  - Enthusiasts (touring and sports) profile drivers (eventual usage)
  - South Europe regions
    - Used throughout the year
    - More common than in northern regions
  - North Europe regions
    - Not usually used in cold weather season

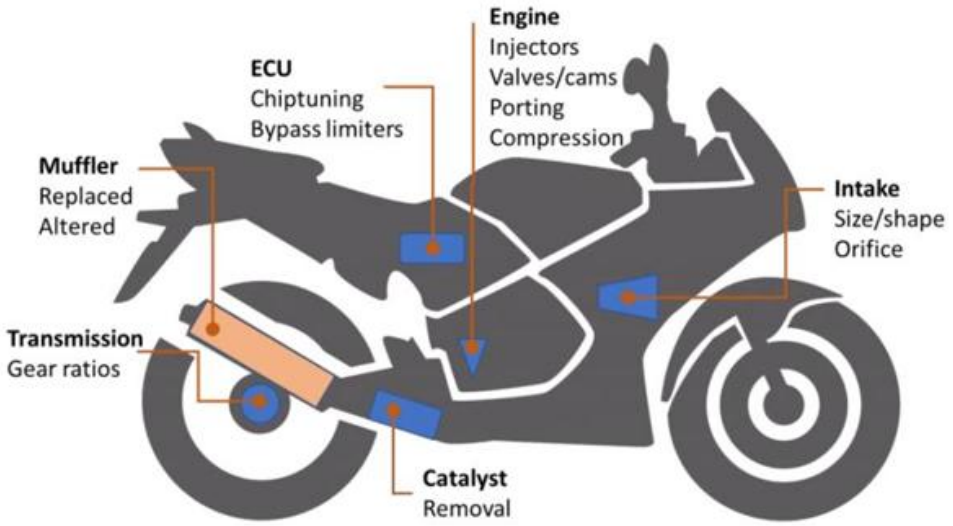


Source: ACEM, 2022 (www.acem.eu)

LENS L-vehicles Emissions and Noise mitigation Solutions

Explanation of L-Category Vehicles

- Tampering occurs on L-Category vehicles
  - Survey for tampering evaluation
    - +600 samples
    - +20 EU Countries
  - Assessment of undesirable effects to be conducted:
    - Noise emissions
    - Pollutants emissions
    - Fuel consumption
  - Most common tampering methods
    - Exhaust
    - Air intake
    - ECU

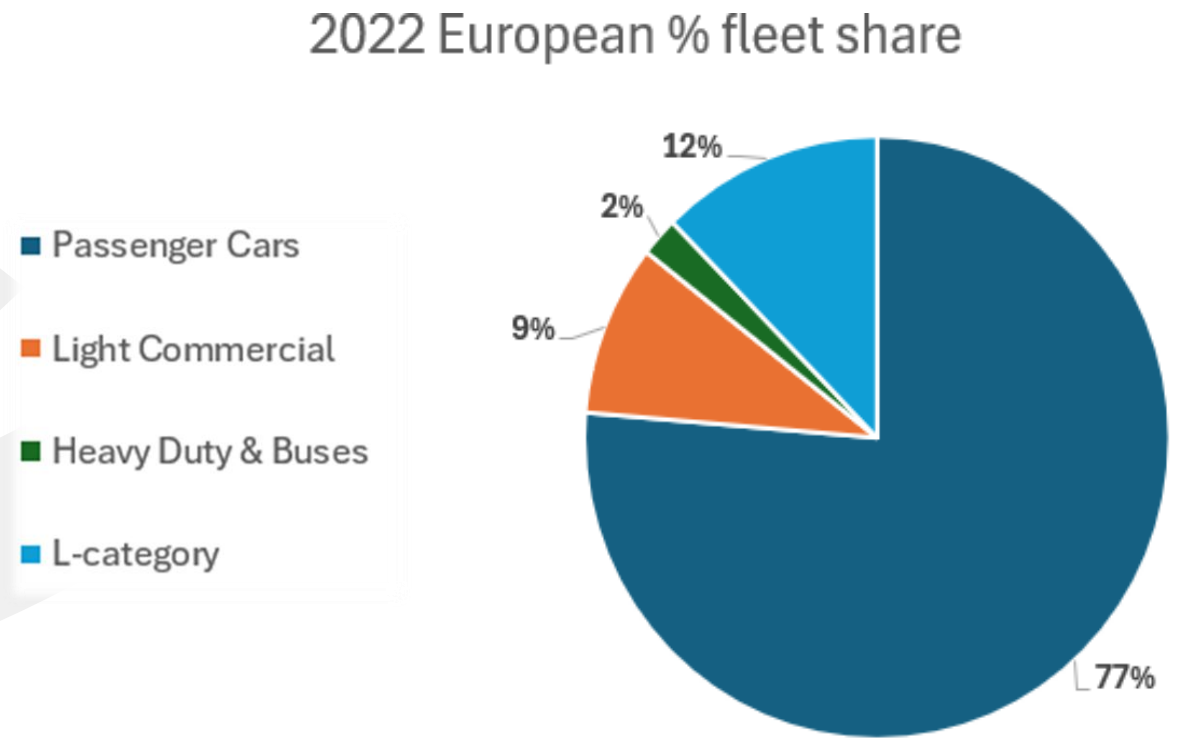


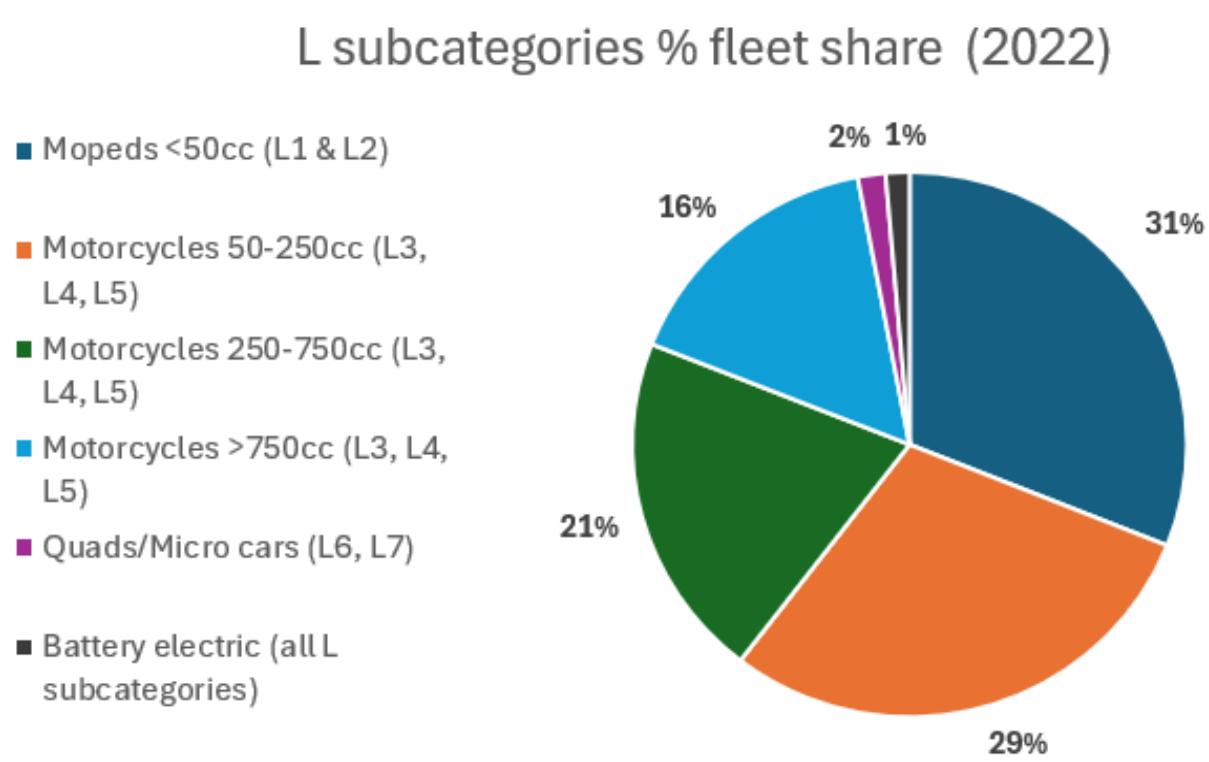
Source: LENS_D5.1_LVs tampering and undesirable effects, 2023 (LENS)

L-vehicles Emissions and Noise mitigation Solutions

Population of L-Vehicles & Sub-Categories

- EU road vehicle fleet: 327 million vehicles (2022 data)





Sources: 1. ACEA, 2022 (www.acea.auto) , 2. ACEM, 2022 (www.acem.eu)

Source: ACEM, 2022 (www.acem.eu)

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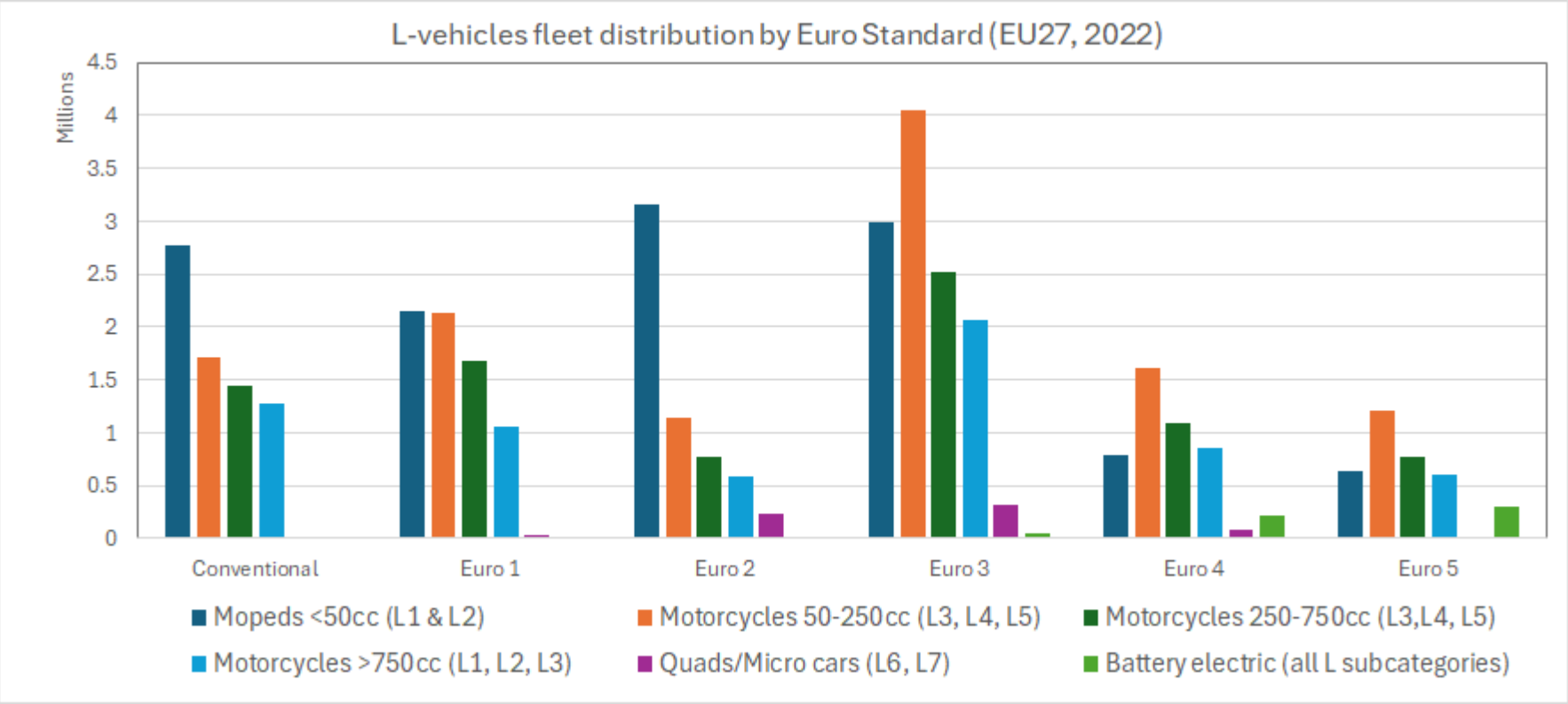
Population related to Emission Classes



Source: ACEM, 2022 (www.acem.eu)

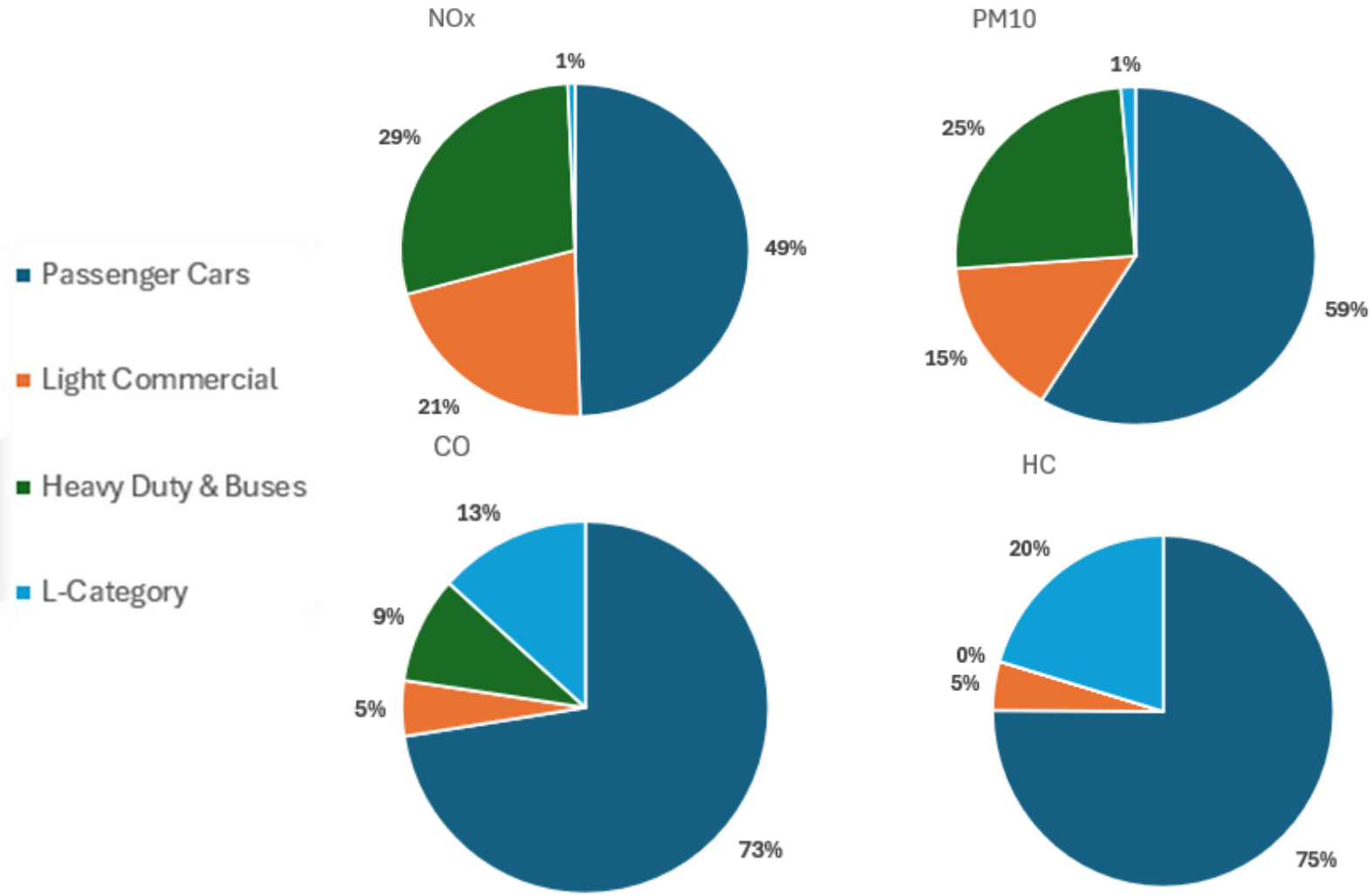
Important outcomes

- Dominance of Euro 3: highest number of L-category vehicles are classified under Euro 3, strong presence of 4-stroke motorcycles
- Few Euro 5 vehicles: indicating a slow transition. Old L-cat fleet.
- Battery electric vehicles remain a minority
- Mopeds have a significant decline in newer Euro categories

L-vehicles Emissions and Noise mitigation Solutions

Impact on Overall Emission

- Distribution of emission of the current fleet in road transport sector



Source: COPERT software

Important outcomes

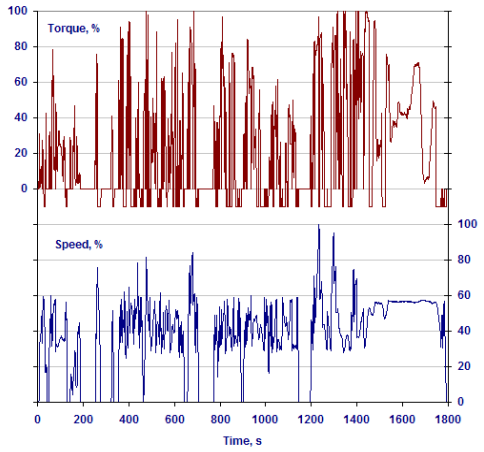
In 2022, L-category has significant impact on:

- ❑ CO emissions ~13%
- ❑ HC emissions ~ 20%

LENS L-vehicles Emissions and Noise mitigation Solutions

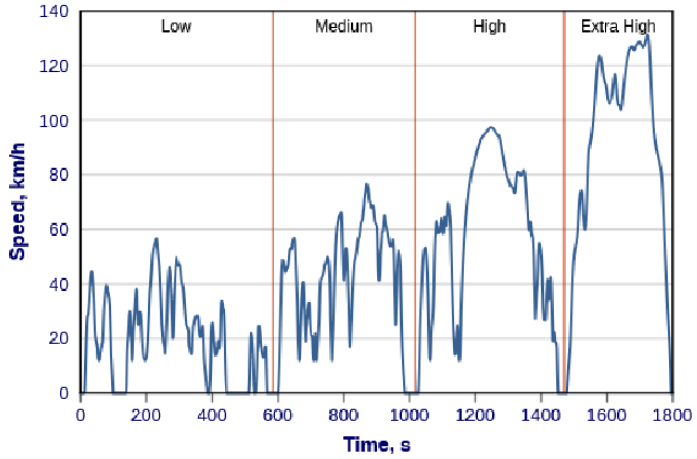
Comparison to PC & HD Vehicles

R(EU) 582/2011 Heavy-duty vehicles



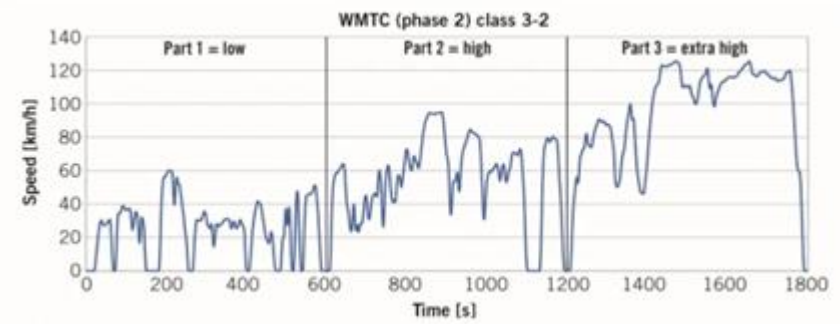
- Laboratory testing for engines
- Pollutants: THC, CO, NOx, PM, PN and CH4
- PEMS testing applicable from 2013

R(EU) 2017/1151 Light-duty vehicles



- Laboratory testing for complete vehicle
- Pollutants: THC, CO, NOx, PM and PN
- RDE testing applicable from 2017

R(EU) 168/2013 L-category vehicles



- Laboratory testing for complete vehicle
- Pollutants: THC, CO, NOx and PM
- RDE: N/A

LENS L-vehicles Emissions and Noise mitigation Solutions

Comparison to PC & HD Vehicles

R(EU) 582/2011 Heavy-duty vehicles

Heavy Duty According to Euro VI-d Standard									
Procedure	NH3	CH4	CO	THC	NMHC	HC+NOx	NOx	PM	PN
	ppm	g/kWh							
WTHC	10	0.5	4	0.19	0.16		0.46	0.01	6.0 10e+11
RDE	10	0.65	1.9	0.16	0.12		0.55	0.014	7.5 10e+11

R(EU) 2017/1151 Light-duty vehicles

Passenger Cars According to Euro 6d Standard								
Procedure	Powertrain	CO	HC	NMHC	HC+NOx	NOx	PM	PNt
		g/km						#/km
WMTC	Petrol	1.0	0.10	0.068	-	0.06	0.0045	6.0 E+11
	Diesel	0.50	-	-	0.17	0.08	0.0045	6.0 E+11
RDE	Petrol	1	0.1	0.068	0.17	0.06	0.0045	6.0 E+11
	Diesel	0.5	-	-	0.17	0.08	0.0045	6.0 E+11

R(EU) 168/2013 L-category vehicles

PM is for DI & CI engines only

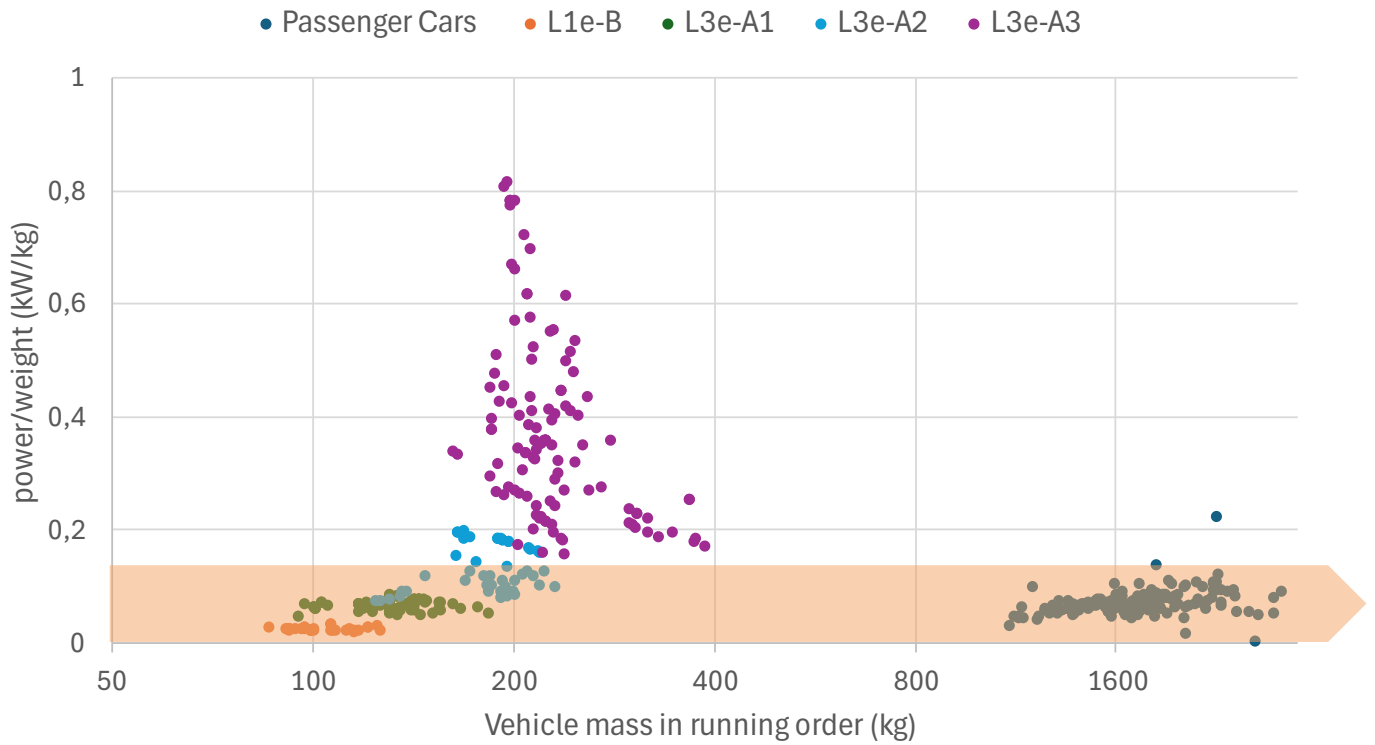
L-Category vehicles According to Euro 5 Standard							
Procedure	Category	Powertrain	CO	THC	NMHC	NOx	PM
			g/km				
Revised WMTC	L1e-A	All	0.5	0.1	0.068	0.06	0.0045
	L1e-B - L7e	Petrol	1	0.1	0.068	0.06	0.0045
		Diesel	0.5	0.1	0.068	0.09	0.0045

*Euro 5 thresholds for L-category vehicles are the same as those for Euro 6 Light Duty vehicles

L-vehicles Emissions and Noise mitigation Solutions

Comparison to PC & HD Vehicles

- Power-to-weight ratio



Porsche 911 GT3RS
0,25 kW/kg

VW Golf TDI
0,07 kW/kg

Typical P/W Ratio for passenger cars

- L-category vehicles have much higher power-to-weight ratio than passenger cars.

Sources: 1. Sebastian Schurl, TU Graz, 2025 , 2. IDIADA, 2025

L-vehicles Emissions and Noise mitigation Solutions

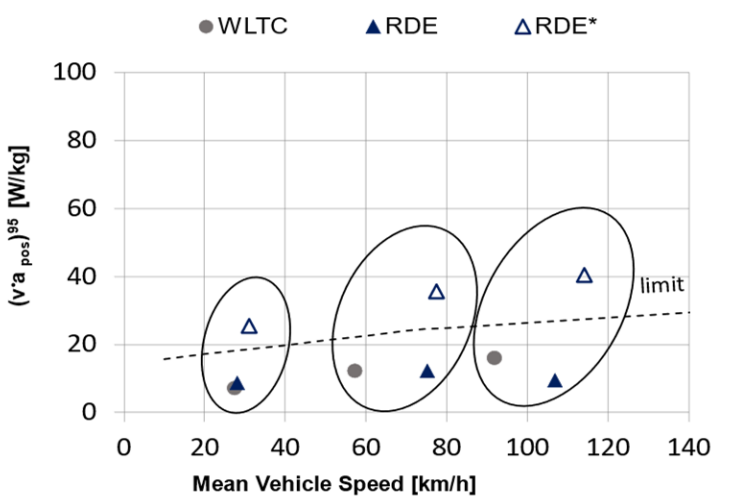
Comparison to PC & HD Vehicles

- Driving dynamics

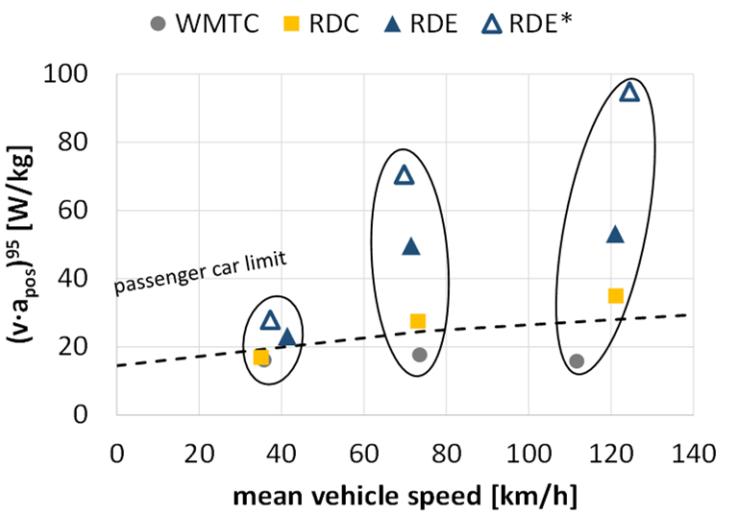
  - Example of driving dynamics (v·a,pos 95th) and engine map of a passenger car and a L3e-A3 motorcycle.

  - Much higher driving dynamics in L-category vehicles than in Light-duty vehicles. Limits cannot be adopted. Limits of on-road testing in L-category vehicles should be defined.

Passenger car



Motorcycle L3e-A3



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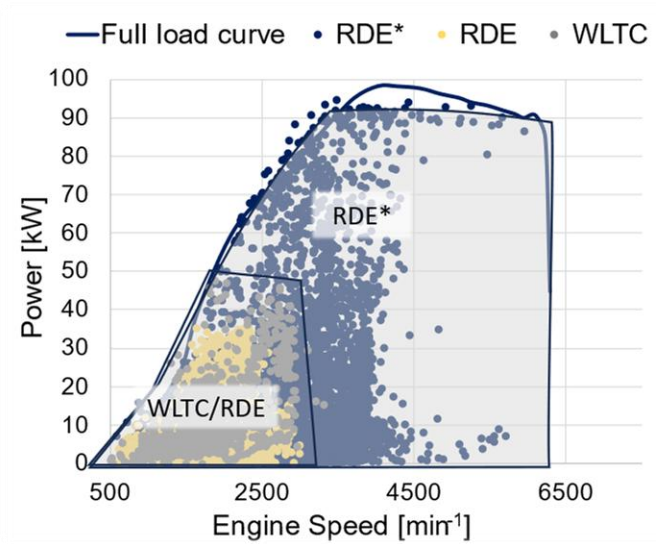
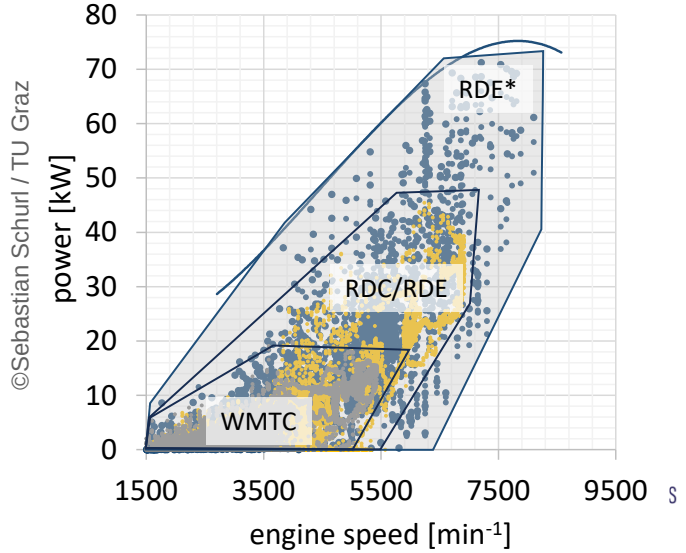
Source: IDIADA, 2025





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Source: IDIADA, 2025