CISMOB
Interreg Europe

universidade de aveiro

Technical paper 9

Analysis of the results on road traffic emissions and related costs in 2014 for the regions of CISMOB consortium

Authors: E. Macedo, P. Tafidis, J.M. Bandeira, M.C. Coelho, J.P. Santos, C. Couceiro, C. Laranjeira, C. Rodrigues, M. Niculescu, C. Barbu, F. Pocostales, L. Cuadros, V. Koulolias, M. Glinos

PP1, PP2, PP3, PP4, PP5, PP6

1 Introduction

European Union (EU) has been regulating the vehicle emissions by introducing several Euro standards. Nowadays, only Euro 6 vehicles can be sold in EU [2]. Despite many vehicle technology improvements, the truth is that road transport is still an important source of air pollutants. In particular, road transport is responsible for significant contributions to emissions of several pollutants, such as Carbon Monoxide (CO), Carbon Dioxide (CO2), Nitrogen Oxides (NOX), Hydrocarbons, specially volatile organic compounds (VOC) and non-methane volatile organic compounds (NMVOC), and particulate matter (PM). According to the European Environment Agency report [1], fuel combustion in transport is responsible for approximately 80.2 million tonnes of annual greenhouse gas emissions in Spain, 16 in Portugal and Romania, and more than 18

European Union
European Regional
Development Fund

million tonnes in Sweden.

This report provides the results of a study on major pollutant on-road emissions for all relevant road vehicle types for the year 2014 based on Portugal, Romania, Spain and Sweden car fleet data. The report covers the emissions per country. Moreover, it also present an analysis and results for CISMOB regions: Centro Region (Portugal), Bucharest (Romania) and Extremadura (Spain). The contribution of each vehicle categories to the total of emissions is also considered.

The report is organized as follows:

- Second section presents the methodology and data source used in the study;
- The third section provides a general overview of emissions and related costs in the countries involved in CISMOB project;
- Section 4 presents an analysis in terms of emissions and associated costs for Centro Region, Bucharest-Ilfov and Extremadura;
- Fifth section is devoted to the analysis of emissions and costs by type of vehicle for Centro Region, Bucharest-Ilfov and Extremadura;
- Finally, Section 6 provides a detailed analysis regarding emissions and costs in terms of vehicle technology for Centro Region, Bucharest-Ilfov and Extremadura.

2 Methodology and data sources used

For obtaining the pollutant emissions the software COPERT v.4 [4] was used with Portugal-specific data. All relevant parameters were selected in order to perform the calculation of all factor emissions for all years described on available data of car fleet of Portugal.

To analyze and compare the environmental effects of different types of vehicles, we considered several pollutants, such as CO, CO2, VOC, NMVOC, NOX and PM2.5. We were not able to calculate and present results on the emissions of SO2, since its estimation using COPERT relies on the annual fuel consumption, whose data is entirely filled with zeros. The estimation of costs associated to the emissions of the pollutants PM 2.5, NMVOC and NOX are based in the damage costs of main pollutants from transport, in € per tonne (2010), from [3]. We also estimate the costs with CO2 based on the information provided in the same reference, where it is considered a cost of 90€ per tonne.

The damage costs values for each country of the CISMOB consortium are displayed in the following table.

Country	CO2	NMVOC	NOX	PM 2.5		
				highway	rural	urban
Portugal	90	1048	1957	18371	49095	196335
Romania		1796	22893	56405	84380	231620
Spain		1135	4964	14429	48012	195252
Sweden		974	5247	14578	50210	197450

Table 1. Damage costs of main pollutants from transport, in € per tonne [3].

The estimates of emissions in this report are based on the results provided by the COPERT traffic emission model [4]. Emissions were calculated using the COPERT v.4 software and COPERT database format. We

manage to have access to COPERT countries data. The COPERT vehicle fleet and activity data is obtained using the latest official statistics available. Data include several Excel sheets of, e.g., population, mileage in km/year, percentage of activity on urban, rural and highway areas, … For specific regions, such as Centro Region, Bucharest and Extremadura, the proportion inside each vehicle category was estimated based on the respective national composition.

Regarding the estimation of costs, we computed the emissions and then, calculated the costs based on the reference values from Table 1. We also computed the associated costs per km of several pollutants, taking into account the travelled mileage.

3 General overview on CISMOB consortium countries

In what follows, there will be presented estimations of emissions and associated costs for Portugal, Spain, Romania and Sweden.

3.1 Emissions

Next table shows Portugal has the lowest level of emissions for CO, VOC and NMVOC, while Romania has lowest values of CO2 emissions, and Sweden has the lowest values for NOx and PM2.5. Spain presents the highest levels on emissions for all pollutants. Comparing Portugal and Spain levels, it can be observed that Spain has, in average, more than four times more emissions than Portugal. Regarding CO2, Romania presents lower values than other countries, and Spain's CO2 emissions are almost six times the emissions in Romania.

	Portugal	Spain	Romania	Sweden
CO	73489,37	474644,07	174180,63	120446,10
CO2	16772324,58	81425214,65	13937501,01	19831802,82
VOC	16376,31	124002,30	31816,49	17439,13
NMVOC	15417,81	118558,34	30451,74	15913,39
NOX	67456,50	390487,05	81315,65	60651,02
PM2.5	3914,24	18412,49	3573,83	2856,06
PM2.5 (urban)	2064,62	8707,01	2138,87	1385,26
PM2.5 (rural)	663,31	3513,22	885,90	1155,37
PM2.5 (highway)	1186,31	6192,25	549,05	315,43

Table 2. Annual emissions for each country in 2014, in tonnes.

3.2 Costs

The following table and figures show the costs with each of the total annual emissions of the pollutants CO2, NMVOC, NOX and PM2.5, for each studied country for the specific year of 2014, corresponding of most recent official data.

	Portugal	Spain	Romania	Sweden
CO2	1509,509	7328,269	1254,375	1784,862
NMVOC	16,158	134,564	54,691	15,500
NOX	132,012	1938,378	1861,559	318,236
PM2.5	459,716	1958,087	601,127	336,130
Total	2117,395	11359,298	3771,752	2454,728

Table 3. Annual costs for each country in 2014, in Million Euros.

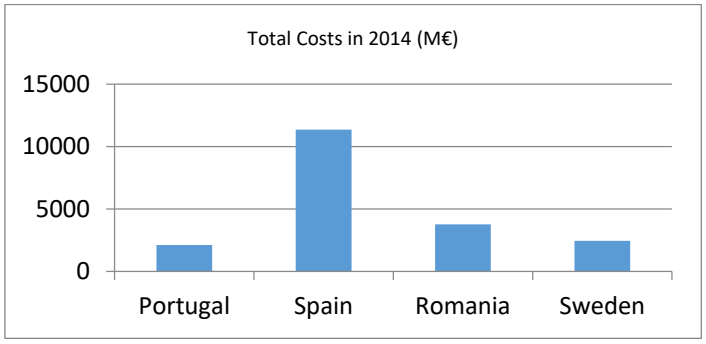

Figure 1. Total annual costs for each country in 2014, in Million Euros.

The first observation is that Spain has the highest total cost, while Portugal presents the lowest. It can be observed that the costs in Spain are 5 times higher than the costs in Portugal. Romania presents costs in the order of one third when compared to Spain. With respect to the costs of Sweden we can see that there were around 337M€ higher than Portugal.

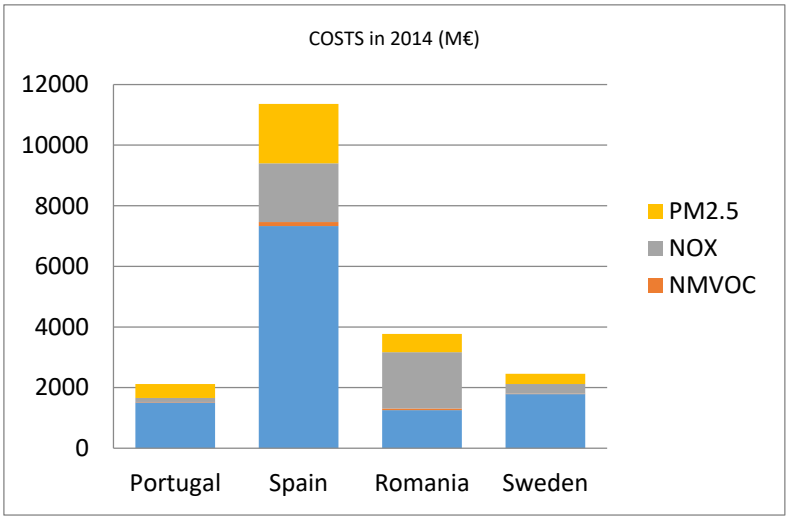

Figure 2. Annual costs specified by pollutant for each country in 2014, in Million Euros.

The above figure shows the costs described by pollutant. It is easy to see that Spain takes the lead, presenting more costs with emissions. Comparing the costs with CO2 between Spain and Romania, which has the lowest, there can be verified a difference of almost 6074M€. On the other hand, Spain also presents the highest costs with NOX emissions, and Portugal the lowest. Comparing such costs, we can see a difference around 1806M€. Comparing the costs with PM 2.5 between Spain (highest) and Sweden (lowest), we can see that the costs of Spain are almost six times higher than in Sweden. Spain also presents the highest costs with NMVOC emissions, followed by Romania, then Portugal, and finally, Sweden, which presents the lowest values. Comparing the highest and lowest values, we can see that Spain spends almost eight times more than Sweden. The costs with NMVOC in Portugal are very similar to those from Sweden.

The following table and figure display the costs per km, taking into consideration the total annual costs and the total mileage per country.

	Portugal	Spain	Romania	Sweden
CO2	0,01984	0,02266	0,02756	0,02043
NMVOC	0,00021	0,00042	0,00120	0,00018
NOX	0,00174	0,00599	0,04090	0,00364
PM2.5	0,00604	0,00605	0,01321	0,00385
Total	0,02783	0,03512	0,08287	0,02810

Table 4. Costs per km by each pollutant for each country, based on data from 2014.

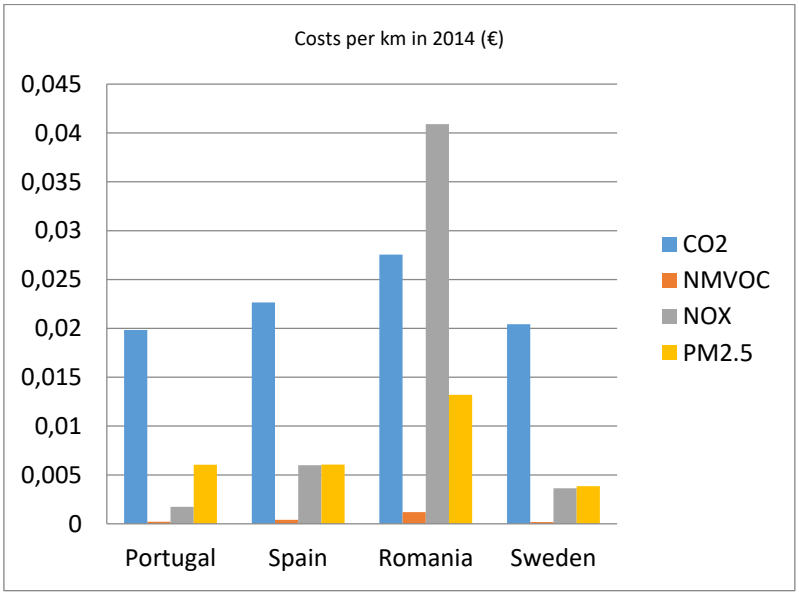

Figure 3. Costs per km for each country specified by pollutant, in Euros.

A first observation is that Romania presents the highest values per km for all pollutants. With respect to the costs per km in Portugal, we can see that the higher values are regarding CO2 emissions, reaching almost

0,02€. Comparing the costs with CO2 between Romania and Portugal, which presents the lowest value, it can be verified that Romania's costs are almost 39% higher than in Portugal. In terms of NOX costs per km, Romania presents 2257% higher costs than Portugal, which once again presents lower values. Moreover, in contrast to the other countries, Romania presents highest costs with NOX than CO2. With respect to PM 2.5 costs per km, we can see that Sweden presents the lowest value, while Romania the higher. There can be verified that Romania presents more than three times higher costs when compared to Sweden. Sweden presents the lowest value for NMVOC, while Romania the higher. Comparing the costs per km of NMVOC in Portugal and Spain, we can see that the costs in Spain are almost two times higher than in Portugal. As a final remark, in terms of total costs per km, Romania has the highest values, followed by Spain, then Sweden, and finally, Portugal, that presents the lowest.

4 Analysis of Centro Region, Bucharest-Ilfov and Extremadura

The following sections are devoted to a comparative analysis of the level of emissions and related costs of the regions addressed in the CISMOB project.

4.1 Total Emissions

The following table shows the total emissions of CO, CO2, VOC, NMVOC, NOX and PM2.5 for all types of vehicles of the studied fleets, concerning 2014.

Pollutant	Centro Region	Bucharest-Ilfov	Extremadura
CO	16807,61362	42300,95111	9143,674626
CO2	3219867,137	3384821,063	2010781,785
VOC	3986,013188	7726,857812	2078,946282
NMVOC	3761,715574	7395,417686	1971,8345
NOX	12506,37923	19748,08602	9804,588675
PM2.5	677,0003208	867,9295217	465,7567642

Table 5. Total emissions in 2014, in tonnes.

The following figure shows more clearly the differences between each studied region. It is displayed using a logarithmic scale.

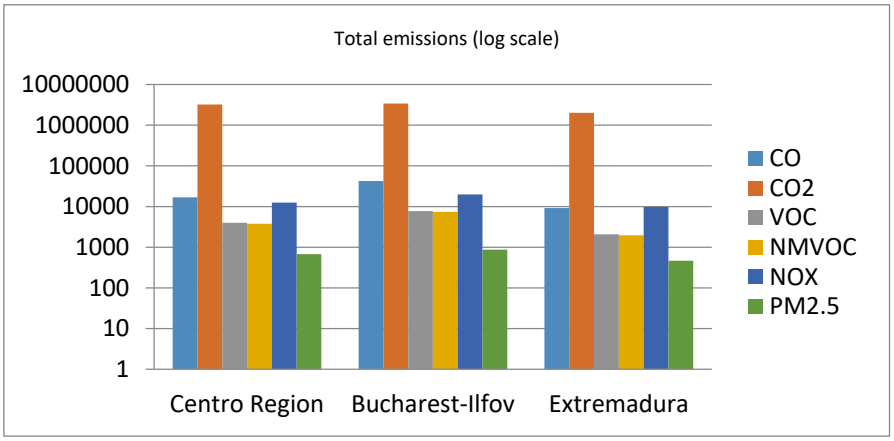

Figure 4. Total emissions per region, in tonnes (logarithmic scale).

Bucharest-Ilfov stands out to be the region, in general, with more emissions. Evidently, the higher emissions are for CO2 in all the regions. Particularly, Bucharest-Ilfov presents the highest levels of emissions for all the pollutants, while Extremadura presents the lowest. NMVOC and VOC emissions are very close to each other in all regions. The ratio NMVOC/VOC is around 0,94, 0,96, and 0,95 for Centro Region, Bucharest-Ilfov and Extremadura, respectively. Overall, we can observe that the graphic of emissions in Centro Region is similar to Extremadura.

4.2 Costs

Table 6 presents total costs of main pollutants for the CISMOB regions, which are illustrated in Figure 5.

	Centro Region	Bucharest-Ilfov	Extremadura
CO2	289,7880424	304,6338957	180,9703606
NMVOC	3,942277922	13,28217016	2,238032157
NOX	24,47498416	452,0929333	48,66997818
PM2.5	73,84940011	145,9880221	49,17673286

Table 6. Total costs in Million Euros.

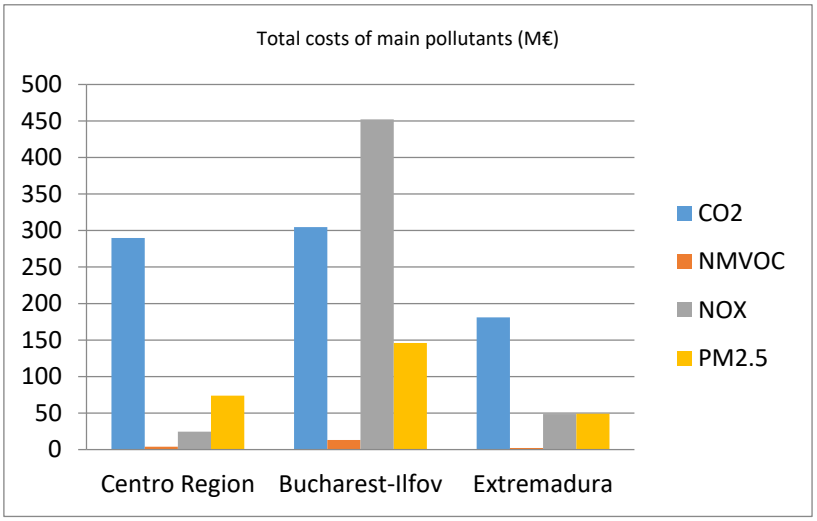

Figure 5. Total costs for main pollutants by region (M€).

The data suggest that Bucharest-Ilfov is the region with the highest costs for all. Regarding NOX, Bucharest-Ilfov presents costs around 450M€, while for the other regions such costs are quite lower. In fact, Centro Region presents the lowest value regarding NOX emission costs (25M€, approximately). With respect to the costs with CO2, we can see that Bucharest-Ilfov is the region that stands out, with costs 68% higher than in Extremadura, which presents the lowest cost. On the other hand, Bucharest-Ilfov presents higher costs with PM 2.5, in particular, such values are almost three times higher than in Extremadura, which presents the lowest costs. Extremadura also presents the lowest costs of NMVOC emissions, while Bucharest-Ilfov presents the highest.

Table 7 presents costs per kilometer (in Euros) of main pollutants for the CISMOB regions, which are illustrated in Figure 5.

	Centro Region	Bucharest-Ilfov	Extremadura
CO2	0,01848806	0,038791647	0,023044509
NMVOC	0,000251512	0,001691333	0,000284988
NOX	0,001561469	0,057568872	0,006197566
PM2.5	0,004711485	0,018589907	0,006262095

Table 7. Costs per km in each region (in Euros).

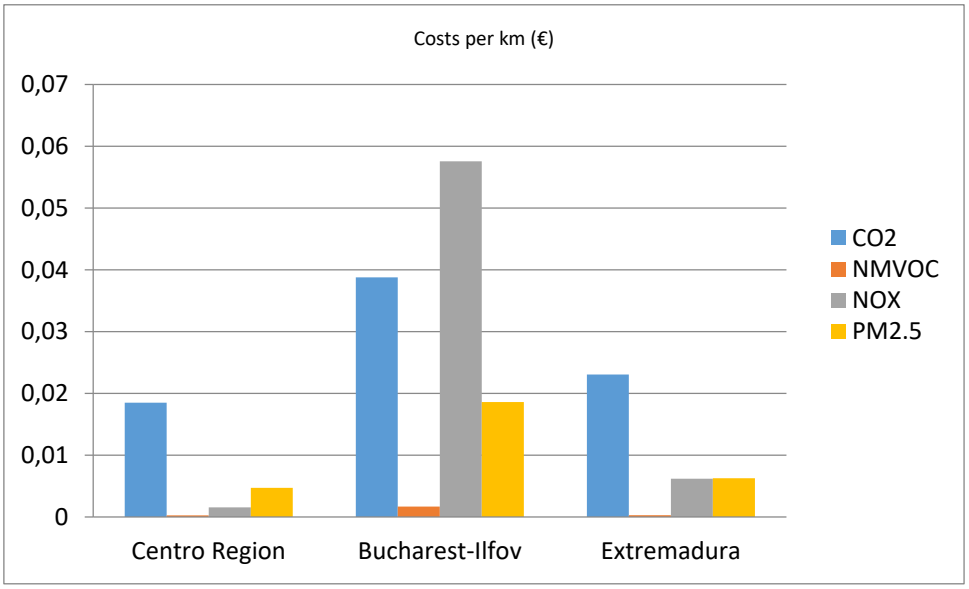

Figure 6. Costs per km in each region (€).

From the above figure we can see that Bucharest-Ilfov stands out to be the region that has the highest costs per km. The costs of NOX in Bucharest-Ilfov are quite high, surpassing the 0,057€, while in Extremadura, such costs are around 0,006€ and in Centro Region are approximately, 0,0016€. With respect to the costs with PM 2.5, it can be observed that Bucharest-Ilfov presents costs quite closer to 0,0181€, while Extremadura presents approximately 0,0063€, and Centro Region, presents the lowest costs, namely, 0,0047€. Centro Region seems to have lower costs per km for all pollutants.

5 Emissions by type of vehicles

This section presents an overview of road traffic emissions considering each type of vehicles: passenger cars, light duty commercial vehicles, heavy duty trucks, buses, mopeds and motorcycles.

5.1 Centro Region

The following figure is displayed using a logarithmic scale in order to emphasize the differences between the pollutant emissions.

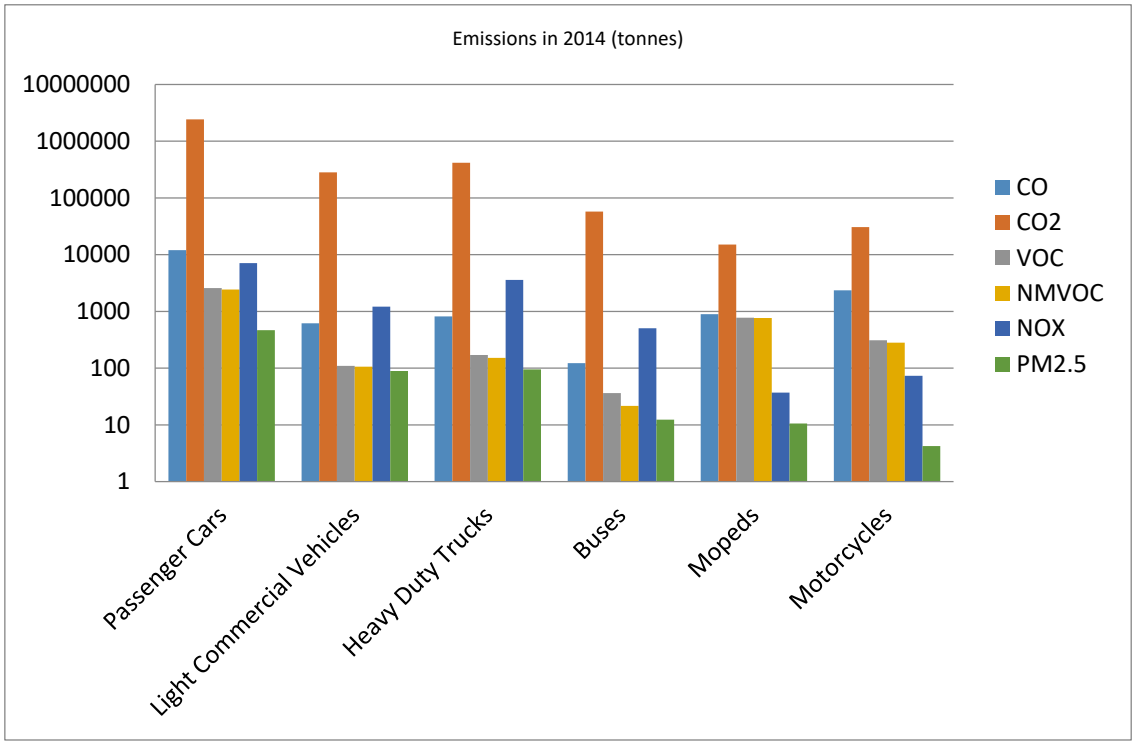

Figure 7. Total emissions in 2014 in Centro Region, estimated for each type of vehicle.

The first observation is that PC are responsible for most of the total emissions. CO2 emissions are higher for PC, HDT and LCV. In contrast to the other cases, we can see that the NOX are higher than the CO emissions for LCV, HDT and Buses. It can be observed that the behavior of VOC and NMVOC are very similar for all types of vehicles. With respect to PM 2.5, motorcycles contribute with the lowest values.

Passenger Cars	Light Commercial Vehicles	Heavy Duty Trucks	Buses	Mopeds	Motorcycles
75%	9%	13%	2%	0,50%	1%

Table 8. Percentage of the total emissions distributed by type of vehicles.

In the Centro Region, PC are responsible for 75% of the total emissions, followed by HDT, with 13%.

5.2 Bucharest-Ilfov

The following figure is displayed using a logarithmic scale.

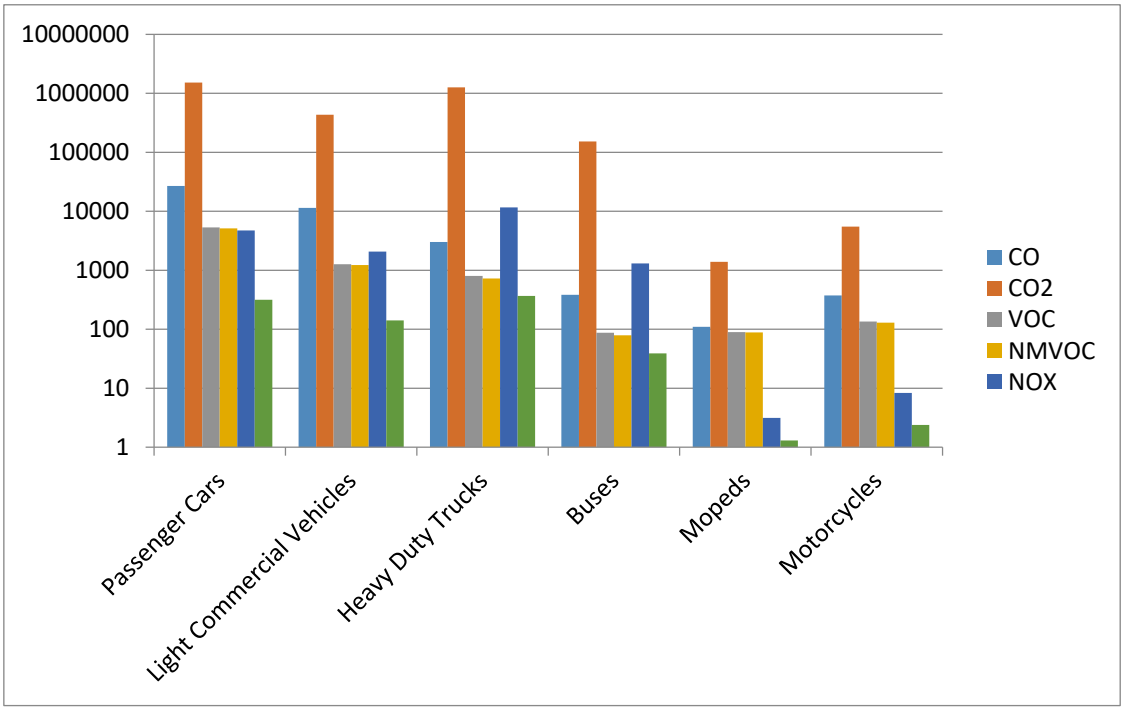

Figure 8. Total emissions in 2014 in Bucharest-Ilfov, estimated for each type of vehicle.

There is a clear difference between the CO2 emissions by mopeds and motorcycles, and the other types of vehicles. PC are responsible for the highest emissions of CO2, CO, VOC and NMVOC, while HDT presents higher emissions of CO and PM 2.5. It can be observed that Mopeds and Motorcycles emit more VOC and NMOVC emissions than buses, while buses clearly emit more CO2, NOX and PM 2.5. HDT and Buses emit more NOX emissions than PC and LCV.

Passenger Cars	Light Commercial Vehicles	Heavy Duty Trucks	Buses	Mopeds	Motorcycles
45%	13%	37%	4,5%	0,05%	0,2%

Table 9. Percentage of the total emissions distributed by type of vehicles.

In the Bucharest-Ilfov, PC are responsible for 45% of the total emissions, followed by HDT, with 37%.

5.3 Extremadura

The following figure is displayed using a logarithmic scale.

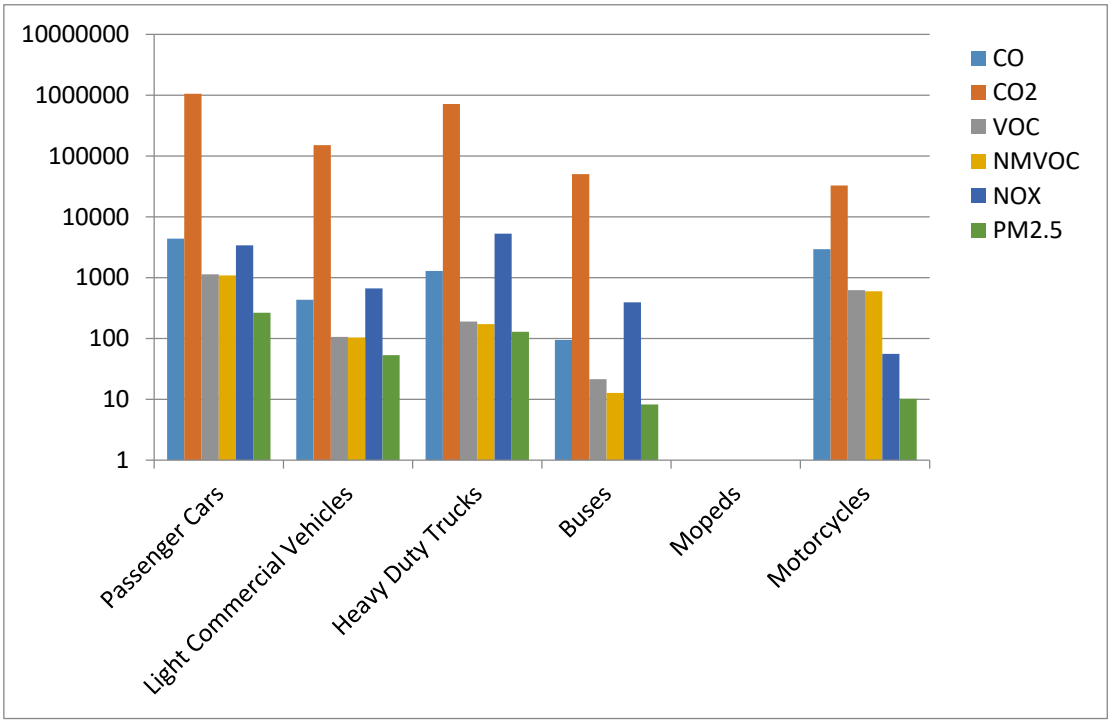

Figure 9. Total emissions in 2014 in Extremadura, estimated for each type of vehicle.

Once again, PC are responsible for most of the total emissions. CO2 emissions are higher for PC, HDT and LCV. We can see that the NOX are higher than the CO emissions for LCV, HDT and Buses. Notice that Motorcycles are responsible for more CO and VOC and NMVOC emissions than HDT. It can be observed that the behavior of VOC and NMVOC are very similar for all types of vehicles. With respect to PM 2.5, Buses contribute with the lowest values, while PC contribute with the highest.

Passenger Cars	Light Commercial Vehicles	Heavy Duty Trucks	Buses	Mopeds	Motorcycles
53%	8%	36%	2,5%	0%	2%

Table 10. Percentage of the total emissions distributed by type of vehicles.

In the Extremadura, PC are responsible for 53% of the total emissions, followed by HDT, with 36%.

6 Analysis of Costs by technology

In this section, an analysis of costs by technology will be presented and described for each main pollutant, namely, CO2, NMVOC, NOX and PM2.5.

6.1 CO2

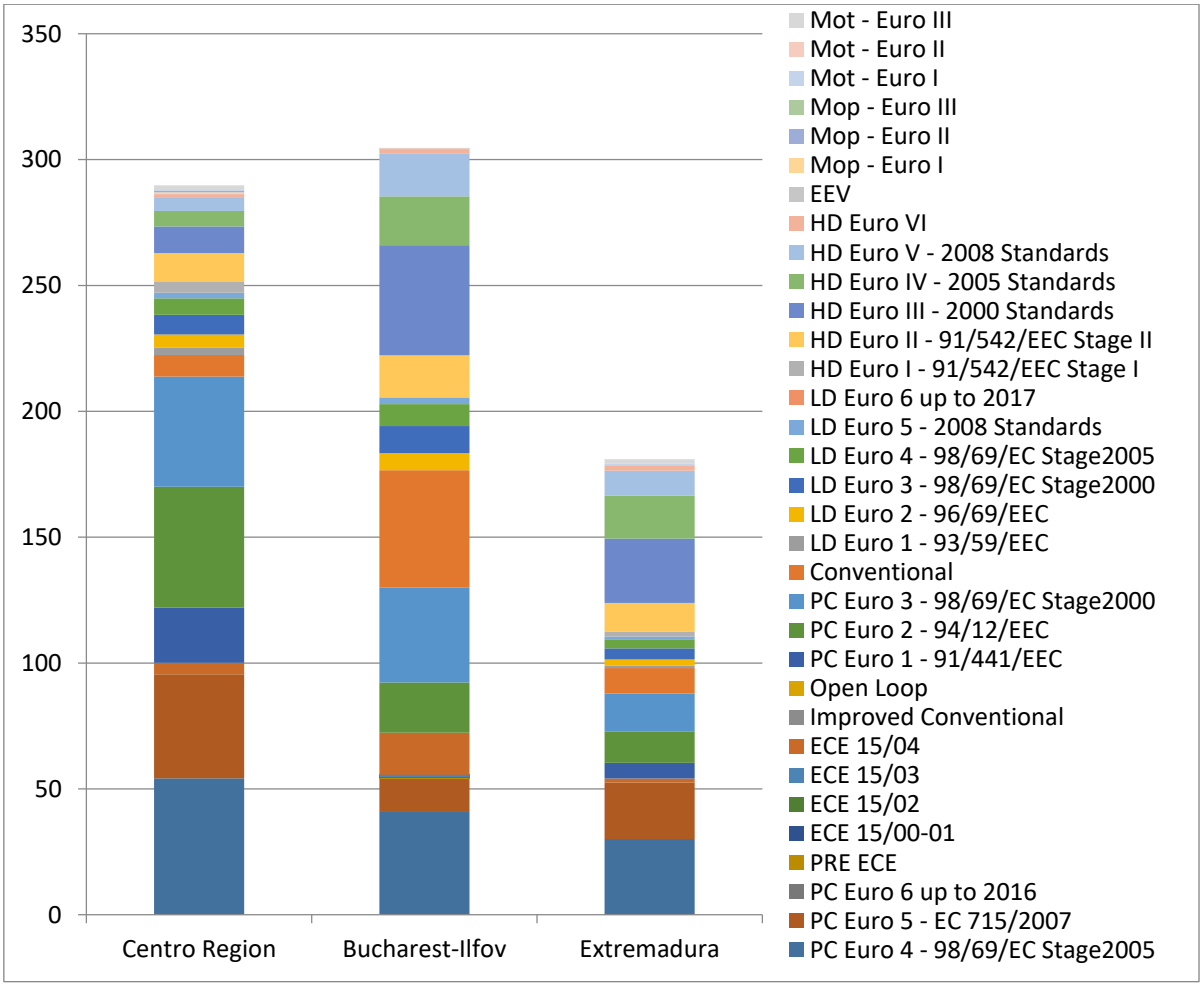

Figure 10. Total Costs of CO2 by technology in Million €.

The above figure suggests that Extremadura presents less total costs than Centro Region and Bucharest-Ilfov, while the Bucharest-Ilfov region presents the highest costs. It can be seen that the most contributing technology is different for each of the regions. Indeed, for Centro Region, the most contributing technologies are PC Euro 4, PC Euro 2, PC Euro 3 and PC Euro 5. These vehicles were responsible for almost 65% of the total costs. Regarding the Bucharest-Ilfov region, we can see that the most contributing technologies are Conventional, HD Euro III, PC Euro 4 and PC Euro 3, which are also responsible for more than 55% of the costs. With respect to Extremadura, the most contributing technologies are PC Euro 4, HD Euro III, PC Euro 5 and HD Euro IV. These vehicles are responsible for almost 53% of the total costs in Extremadura.

Centro Region	Bucharest-Ilfov	Extremadura
289,79	304,63	180,97

Table 11. Total costs with CO2 emissions per region in Million Euros.

6.2 NMVOC

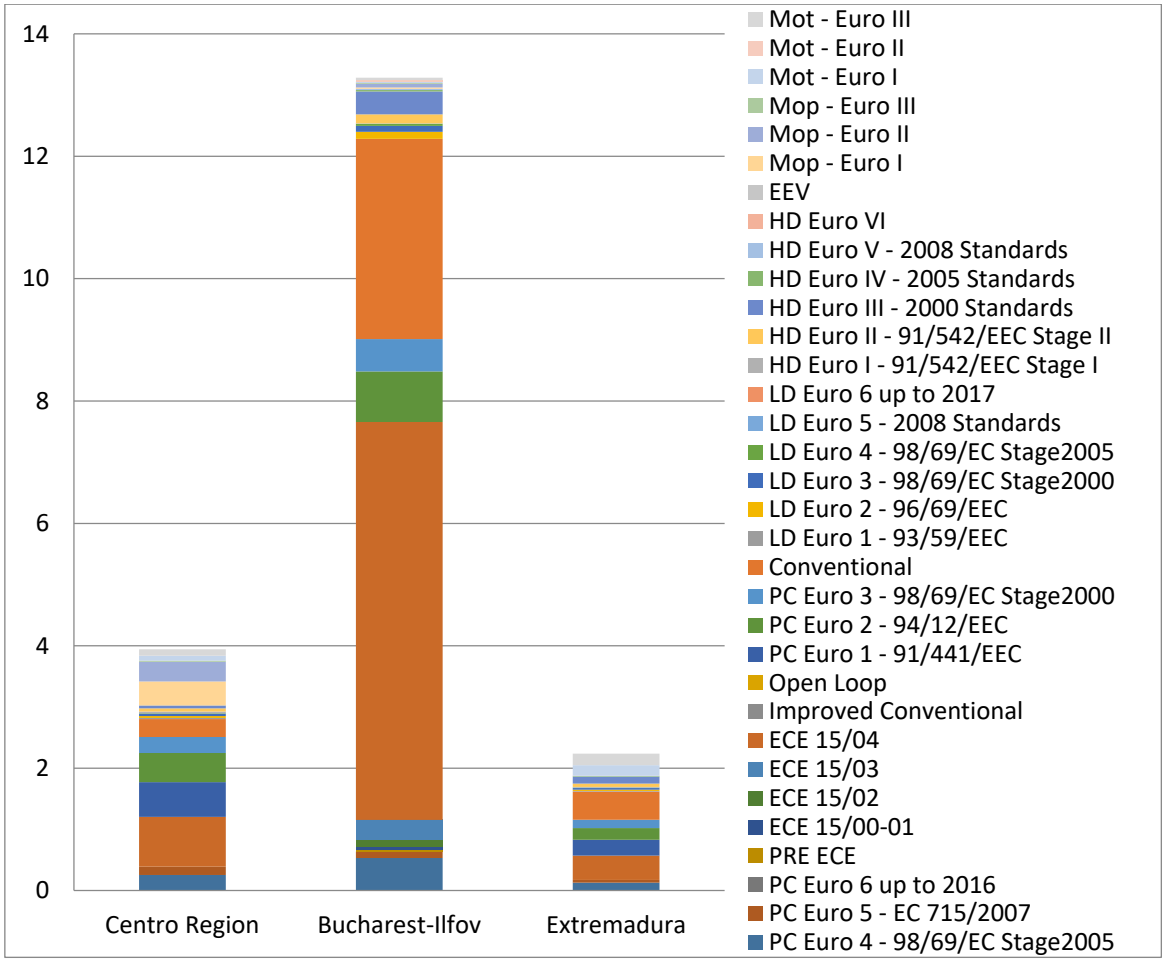

Figure 11. Total Costs of NMVOC by technology in Million €.

Clearly, Bucharest-Ilfov region stands out to be the region with more costs associated to NMVOC emissions. In terms of total costs, we can see that for this region, such costs surpass the 13M€, while Centro Region presents almost 4M€ and Extremadura presents the lowest value, which is around 2,2M€. With respect to the most contributing technologies, the figure shows that for Centro Region, ECE 15/04, PC Euro 1, PC Euro 2, Mop Euro I and Mop Euro II. These vehicle technologies are responsible for almost 45% of the costs in Centro Region. Regarding Bucharest-Ilfov, we can observe that the most contributing technologies are, by far, ECE 15/04 and Conventional, which contributes with almost 74% of the emission costs. Conventional, ECE

15/04 and PC Euro 1 are the most contributing technologies for the total costs in Extremadura. In particular, such vehicles present costs around 29% of the total costs.

Centro Region	Bucharest-Ilfov	Extremadura
3,94	13,28	2,24

Table 12. Total costs with NMVOC emissions per region in Million Euros.

6.3 NOX

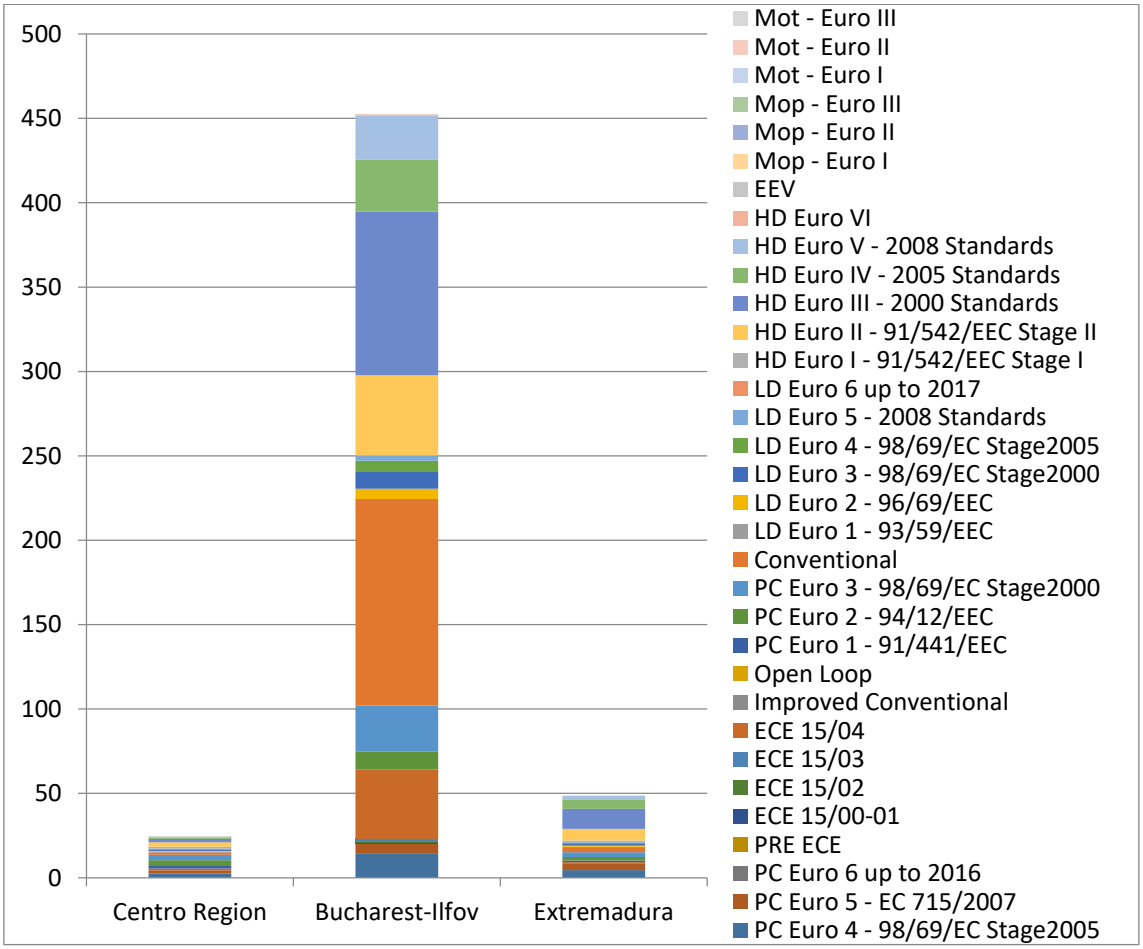

Figure 12. Total Costs of NOX by technology in Million €.

Once again, Bucharest-Ilfov presents the highest costs with NOX. In particular, such costs surpass 450M€, while for Extremadura and Centro Region, the values under 50M€. For the Bucharest-Ilfov case, the most contributing technologies are by far, Conventional, HD Euro III, HD Euro II and ECE 15/04, which are responsible for more than 68% of the total costs. Concerning Extremadura, we can see that the most

contributing technologies are HD Euro III, which reflects almost 25% of the total costs with NOX in this region. In the Centro Region, the PC Euro 2, HD Euro II, PC Euro 4 are the most contributing technologies for the costs. Such vehicles are responsible for 35% of the total costs with NOX.

Centro Region	Bucharest-Ilfov	Extremadura
24,47	452,09	48,67

Table 13. Total costs with NOX emissions per region in Million Euros.

6.4 PM 2.5

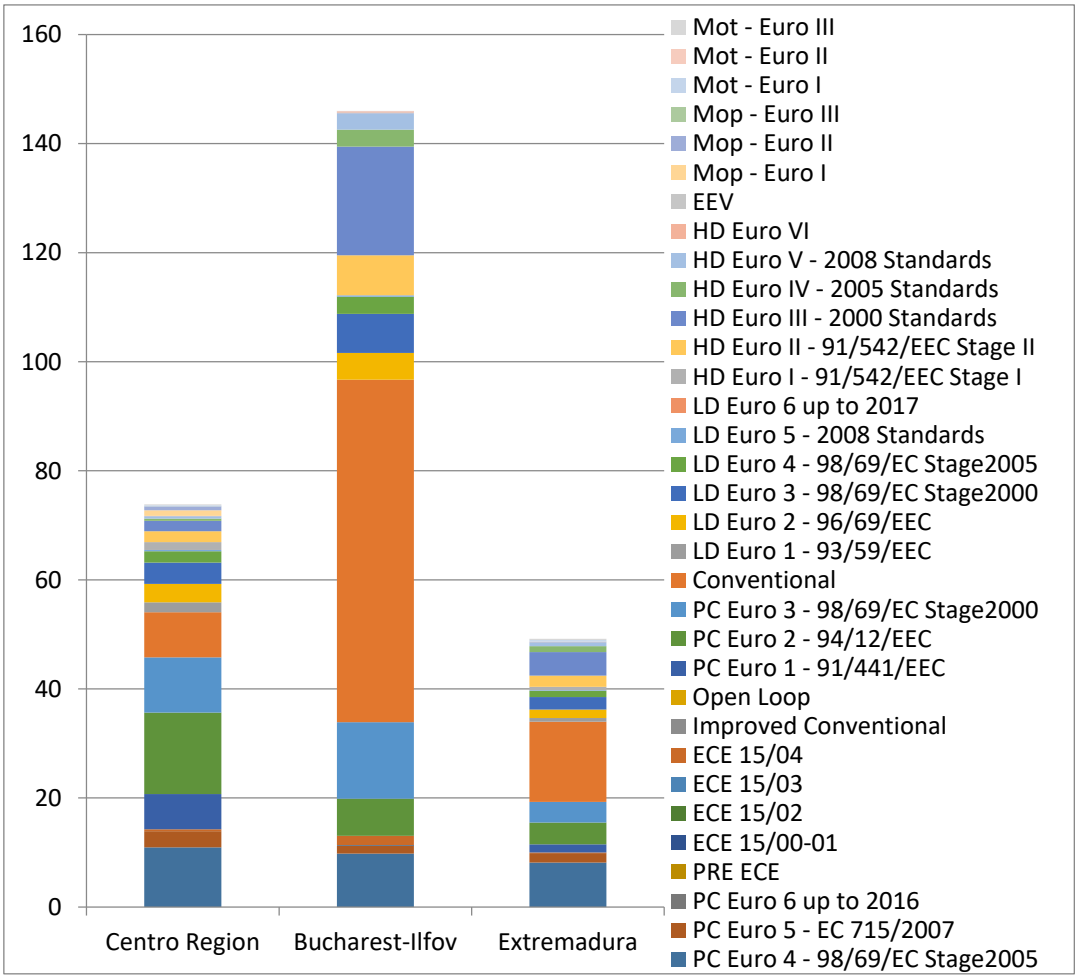

Figure 13. Total Costs of PM 2.5 by technology in Million €.

A first observation is that the total costs in Bucharest-Ilfov is practically the double of Centro Region.

Extremadura presents the lowest costs with PM 2.5. Regarding the costs in Bucharest-Ilfov, the most contributing technologies are by far, Conventional, which represents 43% of the total costs, HD Euro III, PC Euro 3 and 4. In Centro Region, PC Euro 2, 4 and 3 are the most contributing vehicle technologies. Such vehicles are responsible for almost 49% of the total costs. Considering now the results for Extremadura, it can be observed that the most contributing norms are Conventional and PC Euro 4, which represent almost 47% of the total costs.

Centro Region	Bucharest-Ilfov	Extremadura
73,85	145,99	49,18

Table 14. Total costs with PM 2.5 emissions per region in Million Euros.

7 References

[1] EEA - European Environment Agency, *Emissions of greenhouse gases and air pollutants*, 2017, available at http://ec.europa.eu/eurostat/web/environment/air-emissions-inventories/main-tables

[2] EEA - European Environment Agency, *Explaining road transport emissions: A non-technical guide*, EEA Report, 2016, ISBN 978-92-9213-723-6, doi: 10.2800/71804, available at

https://www.eea.europa.eu/publications/explaining-road-transport-emissions

[3] European Commission, DG Mobility and Transport, Update of the Handbook of external costs of transport, Ricardo-AEA – Final Report, London, 2014, available at

http://ec.europa.eu/transport/sites/transport/files/themes/sustainable/studies/doc/2014-handbook-external-costs-transport.pdf

[4] Emisia, 2015, 'Copert 4' (http://emisia.com/copert).