CISMOB
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Technical paper 2

Assessing major pollutant on-road emissions and related costs in Portugal

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PP1

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). In Portugal, for instance, road transport accounts for 24% of total greenhouse gas emissions in 2014 [1].

This report provides the results of a study on major pollutant on-road emissions for all relevant road vehicle types from 2000 to 2014 based on Portugal car fleet data. The report covers the emissions per country. The contribution of each vehicle categories to the total of emissions is also considered.

European Union
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The report is organized as follows:

- Second section presents the methodology and data source used in the study.
- The third section provides an analysis of emissions and related costs in Portugal.

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. 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, …

Regarding the estimation of emissions in Portugal, we computed the emissions and then, calculated the associated costs per km of several pollutants.

3. Analysis of Portugal vehicle fleet emissions

3.1. Total Emissions and Costs

The following table shows the annual emissions of CO, CO2, VOC, NMVOC, NOX and PM2.5 for all types of vehicles of the Portuguese fleet.

	2000	2001	2002	2003	2004	2005	2006	2007
CO	314408,15	274416,36	261727,68	238005,25	215710,73	187031,70	162904,63	141633,79
CO2	18472082,43	18779895,25	19252074,48	19167578,25	19095988,82	18870055,06	19121026,03	18900768,49
VOC	66954,35	58738,12	54213,51	49743,66	45086,47	39922,32	35170,51	30432,66
NMVOC	63779,16	55904,58	51500,33	47248,50	42800,21	37873,87	33365,44	28859,04
NOX	114960,36	112272,59	108962,61	103767,55	99562,25	92943,24	89769,68	84480,31
PM2.5	6990,55	6918,65	6605,75	6315,74	6065,16	5444,48	5272,68	4939,79

	2008	2009	2010	2011	2012	2013	2014
CO	125919,33	117049,74	99777,15	103468,49	88632,56	79931,85	73489,37
CO2	18647297,84	18851030,85	18946285,28	17638450,32	17025626,06	16772165,11	16772324,58
VOC	26853,20	24662,00	21002,21	22086,93	19444,58	17727,82	16376,31
NMVOC	25448,17	23348,75	19863,26	20866,10	18362,77	16718,58	15417,81
NOX	79698,74	77451,79	74111,76	74620,91	71240,86	68947,56	67456,50
PM2.5	4642,94	4525,64	4283,58	4358,37	4170,91	4021,28	3914,24

Table 2. Total emissions in Portugal in tonnes.

The CO2 emission is by far the most contributor to pollute the environment, presenting in 2014 more than 16 million tonnes. Comparing the values of the total amount of emissions of all pollutants between 2000 and 2014, we can see that there was a reduction of approximately 11%. A closer look to the total amount of CO, VOC, NMVOC, NOX and PM2.5 emissions (Figure 1) shows that from 2000 to 2010 there has been a decreasing in those values. In 2011, there was a slight augment, and then it tends to decrease. Comparing the values between 2000 and 2014, we can verify a reduction around 69%.

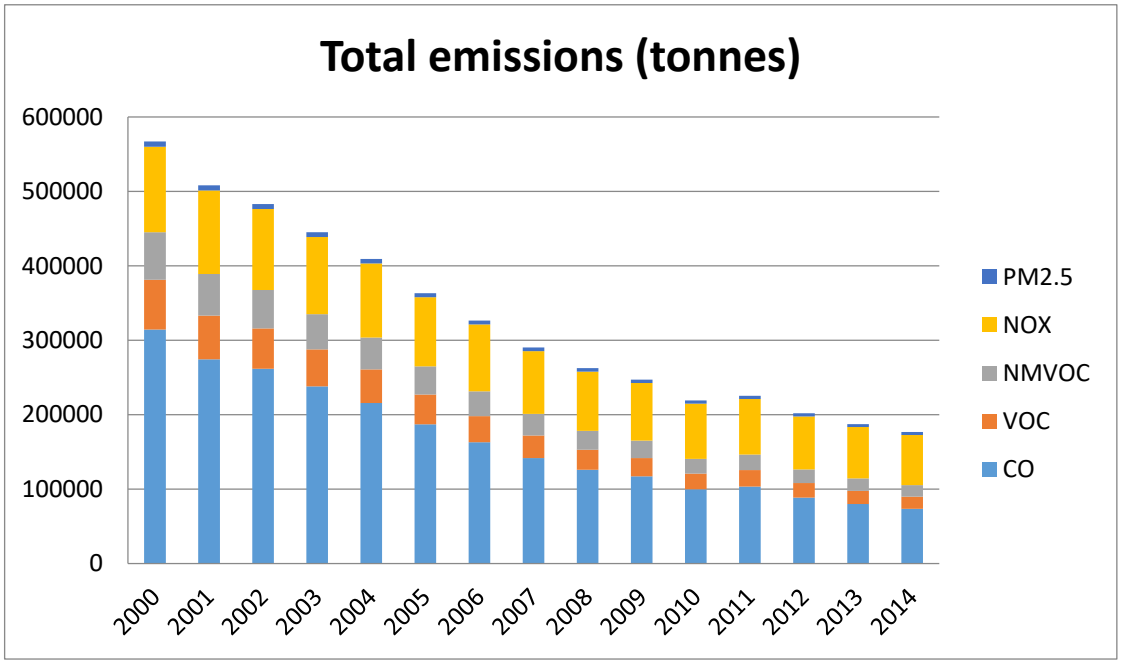

Figure 1. Total emissions of CO, VOC, NMVOC, NOX and PM2.5 (tonnes).

Table 3 presents the emission costs by each pollutant, given in Million Euros, and Figure 2 presents the total costs in Million Euros.

	2000	2001	2002	2003	2004	2005	2006	2007
CO2	1662,49	1690,19	1732,69	1725,08	1718,64	1698,30	1720,89	1701,07
NMVOC	66,84	58,59	53,97	49,52	44,85	39,69	34,97	30,24
NOX	224,98	219,72	213,24	203,07	194,84	181,89	175,68	165,33
PM2.5	857,09	842,36	798,73	761,80	728,42	653,00	631,72	590,50

	2008	2009	2010	2011	2012	2013	2014
CO2	1678,26	1696,59	1705,17	1587,46	1532,31	1509,49	1509,51
NMVOC	26,67	24,47	20,82	21,87	19,24	17,52	16,16
NOX	155,97	151,57	145,04	146,03	139,42	134,93	132,01
PM2.5	554,70	540,15	509,84	513,21	490,59	472,58	459,72

Table 3. Emission costs in Portugal in Million €.

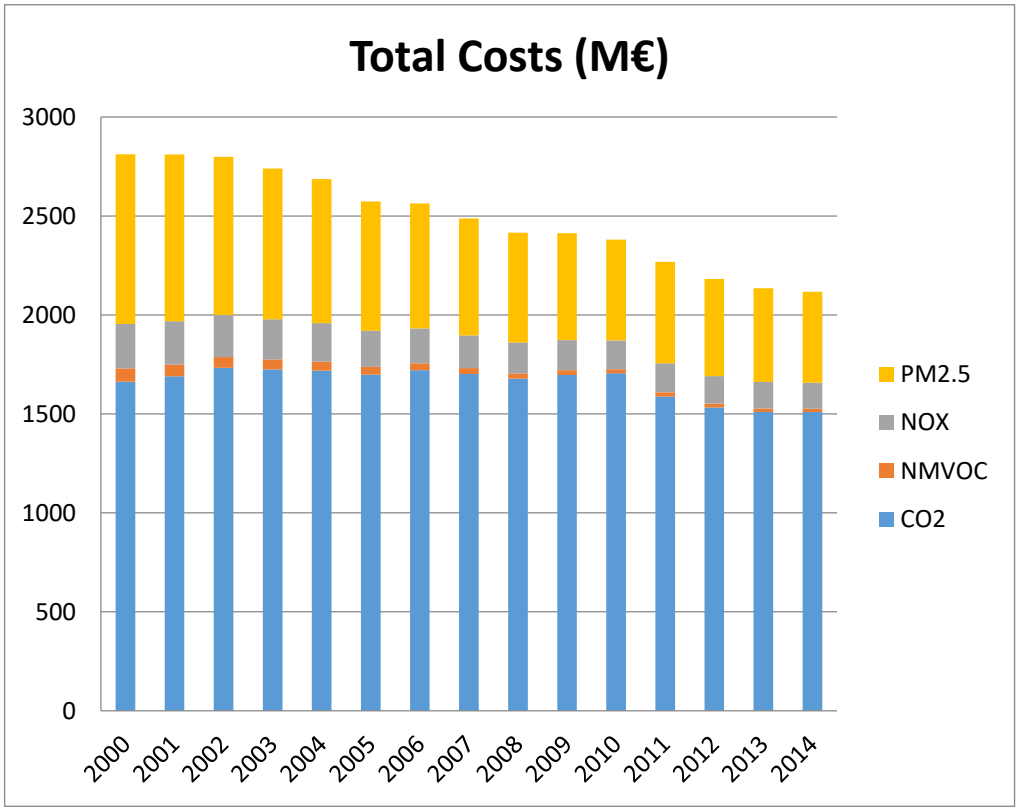

Figure 2. Total costs in Portugal in Million €.

We can see that the costs with CO2 have always been above 1500M€. The costs with NOX and NMVOC have been decreasing over the years, while the costs with PM 2.5 have been decreasing from 2000 to 2010. But in 2011 such values suffer a slight augment, and then they continue the decreasing tendency. Comparing the total costs with the emissions of the studied pollutants in the period between 2000 and 2014, we can verify that there was a reduction of almost 25%.

The following table and figure show the emission costs per km (€/km).

	2000	2001	2002	2003	2004	2005	2006	2007
CO2	0,02104	0,02118	0,02095	0,02078	0,02065	0,02050	0,02039	0,02021
NMVOC	0,00085	0,00073	0,00065	0,00060	0,00054	0,00048	0,00041	0,00036
NOX	0,00285	0,00275	0,00258	0,00245	0,00234	0,00220	0,00208	0,00197
PM2.5	0,01085	0,01056	0,00966	0,00917	0,00875	0,00788	0,00748	0,00701

	2008	2009	2010	2011	2012	2013	2014
CO2	0,02002	0,01984	0,01969	0,01989	0,01992	0,01989	0,01984
NMVOC	0,00032	0,00029	0,00024	0,00027	0,00025	0,00023	0,00021
NOX	0,00187	0,00177	0,00167	0,00183	0,00181	0,00178	0,00174
PM2.5	0,00662	0,00632	0,00589	0,00643	0,00638	0,00623	0,00604

Table 4. Emission costs in Portugal in €/km.

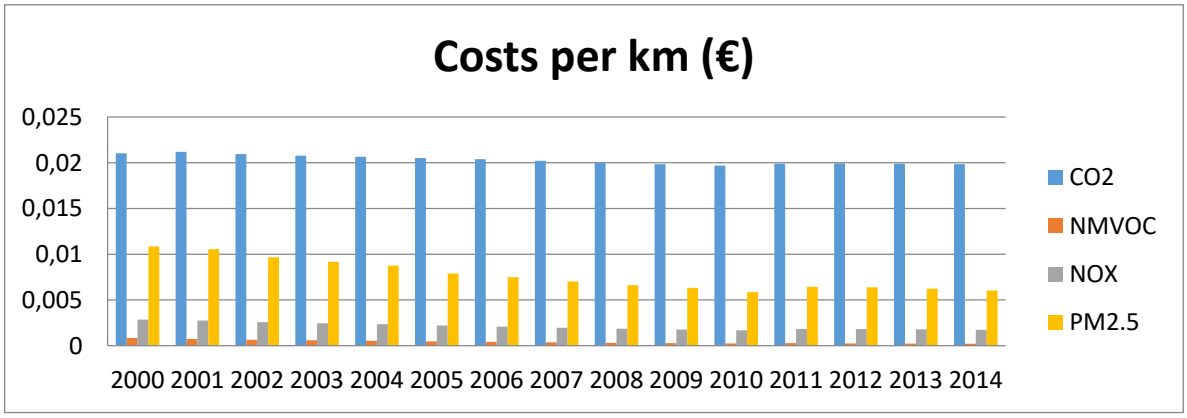

Figure 3. Costs per km (€).

It can be observed that in the studied period, CO2 presents the highest values, sometimes surpassing 0,02€, while NMVOC presents the lowest. The highest values of PM 2.5 were achieved in 2000 and 2001. We can see that the costs with PM 2.5 have in general been decreasing until 2011, where an augment can be verified. After 2011, there is a tendency to stabilize around 0,006€. Comparing the values of NOX between 2000 and 2014, we can observe a reduction around 40%.

3.2. Emissions by type of vehicles

The following figures are displayed using a logarithmic scale (to show magnitude) in order to emphasize the differences between the pollutant emissions.

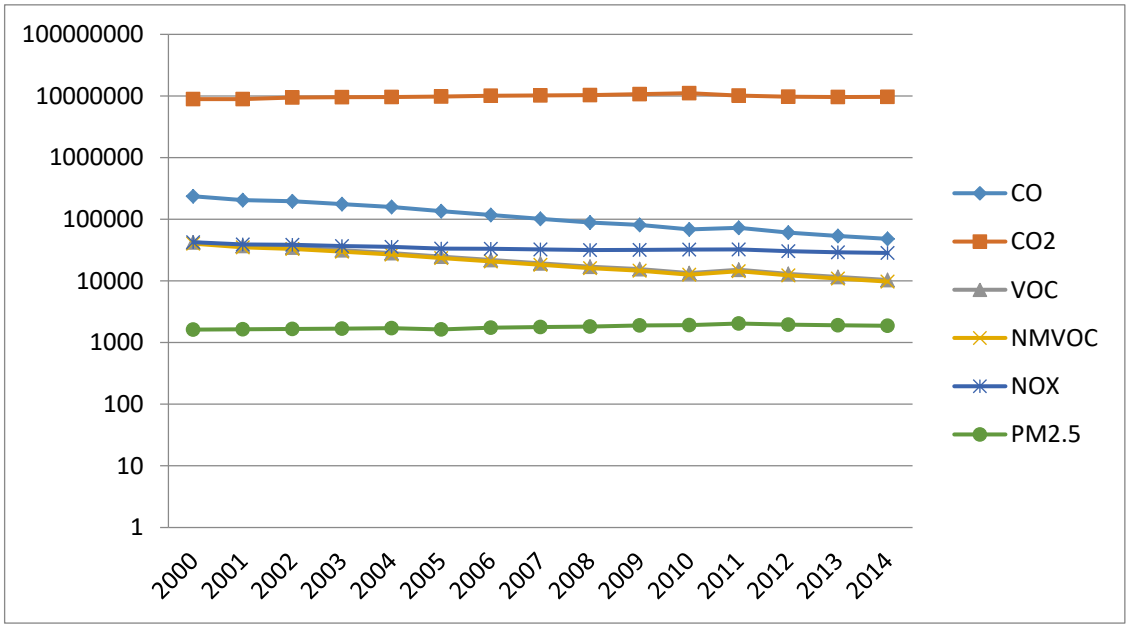

Figure 4. Passenger Cars - annual emissions in tonnes (logarithmic scale).

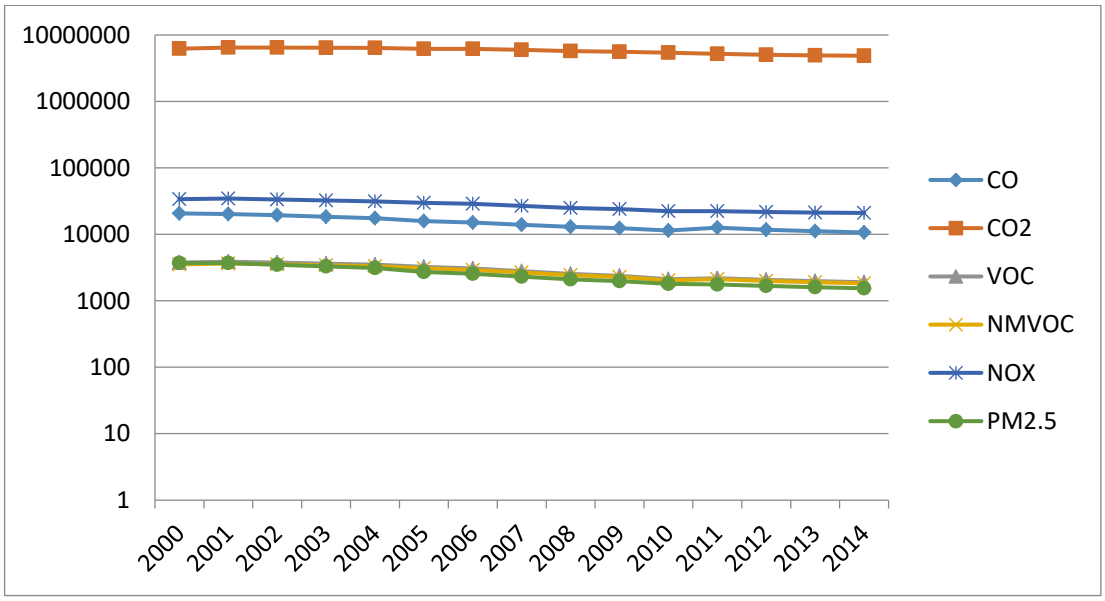

Figure 5. Light Commercial Vehicles - annual emissions in tonnes (logarithmic scale).

Regarding the emissions of pollutants by each type of vehicles, we can see from Figures 4 and 5 that the emissions of CO2 for the passenger cars (PC) are, in average, around 9866903tonnes, while for light commercial vehicles (LCV), such value is approximately 5811497tonnes and exhibiting a decreasing tendency over the years. We can see that PC emit higher levels of CO2 than LCV. With respect to PM 2.5, we can see that, comparing the values in 2000 and 2014, there was an augment of almost 16%, in the case of PC, while for LCV, there was a reduction of approximately 58%. It can be observed that on both cases there is a decreasing tendency for CO, VOC and NMVOC emissions until 2011, where a slight augment is registered. Then, the decreasing tendency prevails. We can see that PC are responsible for more emissions of NOX, when compared to LCV. It can be observed that the emissions of CO are greater than NOX in the case of PC, while in LCV it is the opposite.

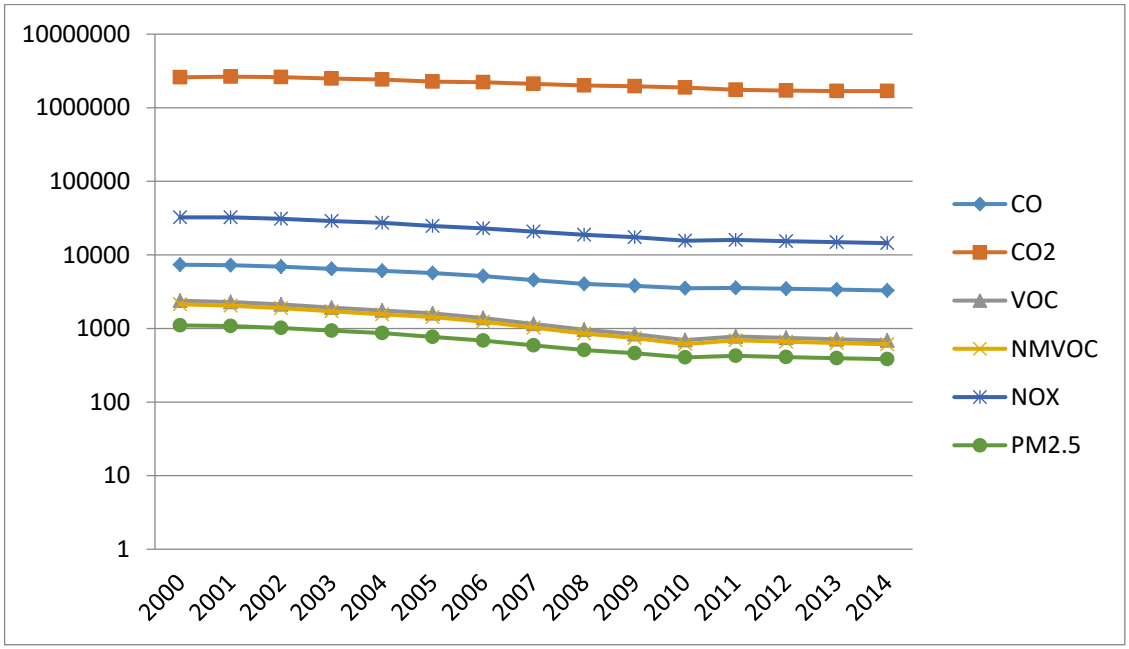

Figure 6. Heavy Duty Trucks – annual emissions in tonnes (logarithmic scale).

It can be observed a decreasing behavior on all emissions from Heavy Duty Trucks until 2011, where there was registered a slight augment (except in CO2). The emissions of CO2 have been decreasing since 2001, but, comparing the levels between 2001 and 2014, there was a reduction of almost 37%. Until 2010, all the other pollutants present a decreasing behavior, more evident in PM 2.5, NMOVC, VOC. It can be observed that the emissions of NOX are always above the emissions of CO.

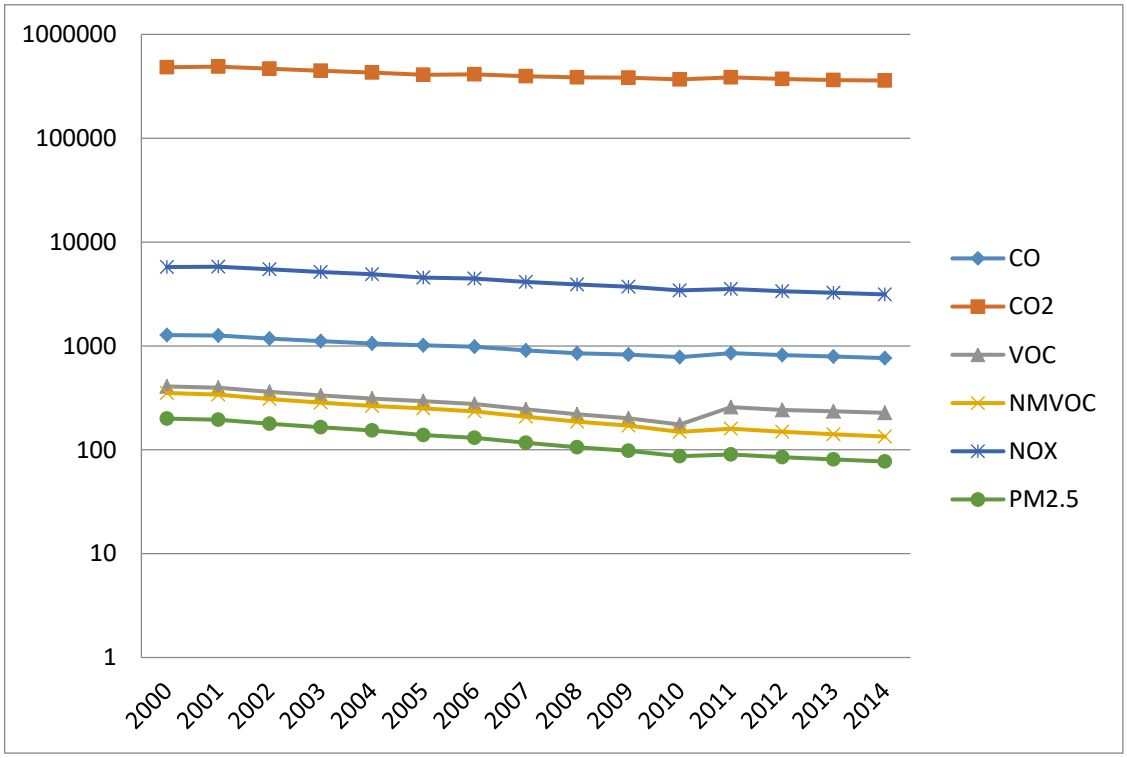

Figure 7. Buses – annual emissions in tonnes (logarithmic scale).

Concerning the buses fleet, the CO2 emissions have in general been decreasing until 2011, where there was an augment. Comparing the highest and the lowest values, in 2001 and 2014, respectively, it can be verified a reduction around 27%. The NOX emissions have also been, in general, decreasing, experiencing a reduction of approximately 45%. It can be observed that over the years the emissions of NOX are quite higher when compared to the emissions of CO. The decreasing behavior from 2000 to 2014 is more evident on the emissions of PM 2.5, NMVOC and VOC. In 2011, those values slightly augment, stabilizing since then.

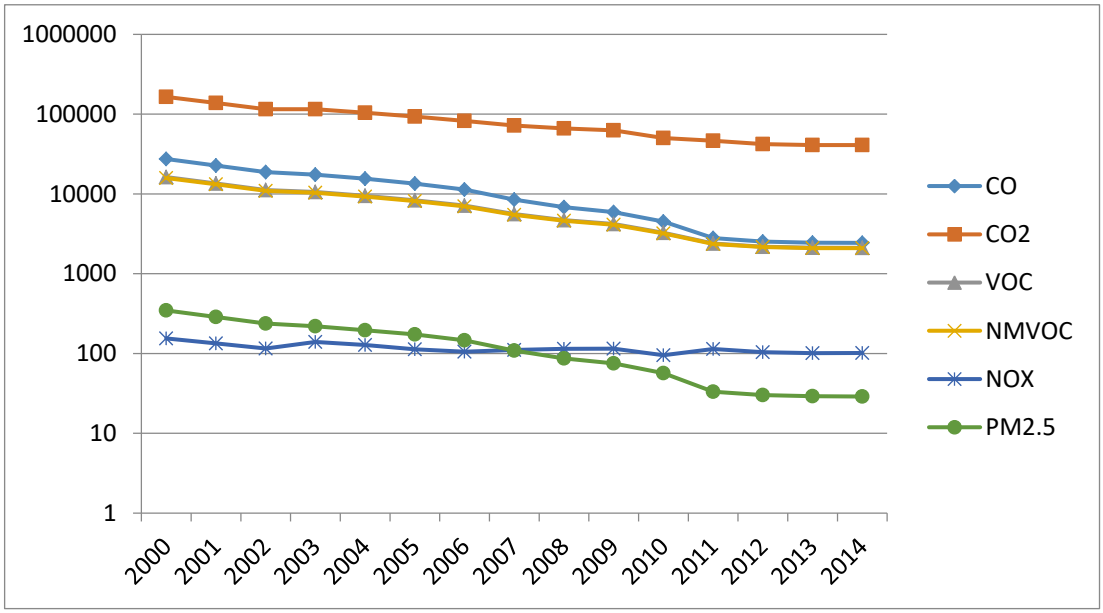

Figure 8. Mopeds – annual emissions in tonnes (logarithmic scale).

It can be observed a decrease in the emissions of CO2 of Mopeds in the studied period. Concretely, comparing the highest and lowest values, achieved in 2000 and 2014, respectively, we can see a reduction of 75%. There was a considerable decreasing behavior over the years for the remaining pollutants, excepting for NOX, which values have been varying between 101 and 155tonnes. Comparing the emissions of PM 2.5 between 2000 and 2014, we can verify a reduction in the order of 92%.

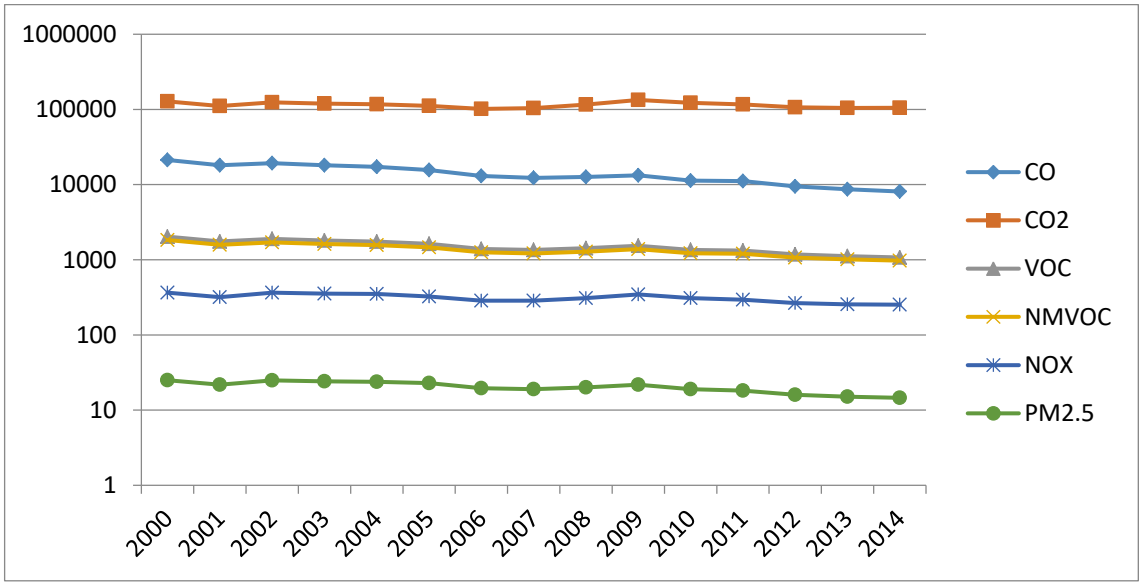

Figure 9. Motorcycles – annual emissions in tonnes (logarithmic scale).

From 2002, the CO2 emissions are higher for motorcycles, than for mopeds. Comparing the values of CO2 emissions in 2000 and 2014, we can see a reduction of almost 18%. It can be observed a decreasing tendency in the studied period on the emissions of the pollutants CO, NMVOC and VOC. In average, there was 312tonnes of NOX emissions in each year. Since 2009, the PM 2.5 emissions have been decreasing reaching in 2014 values around 15tonnes.

3.3. Analysis of Costs by technology – CO2

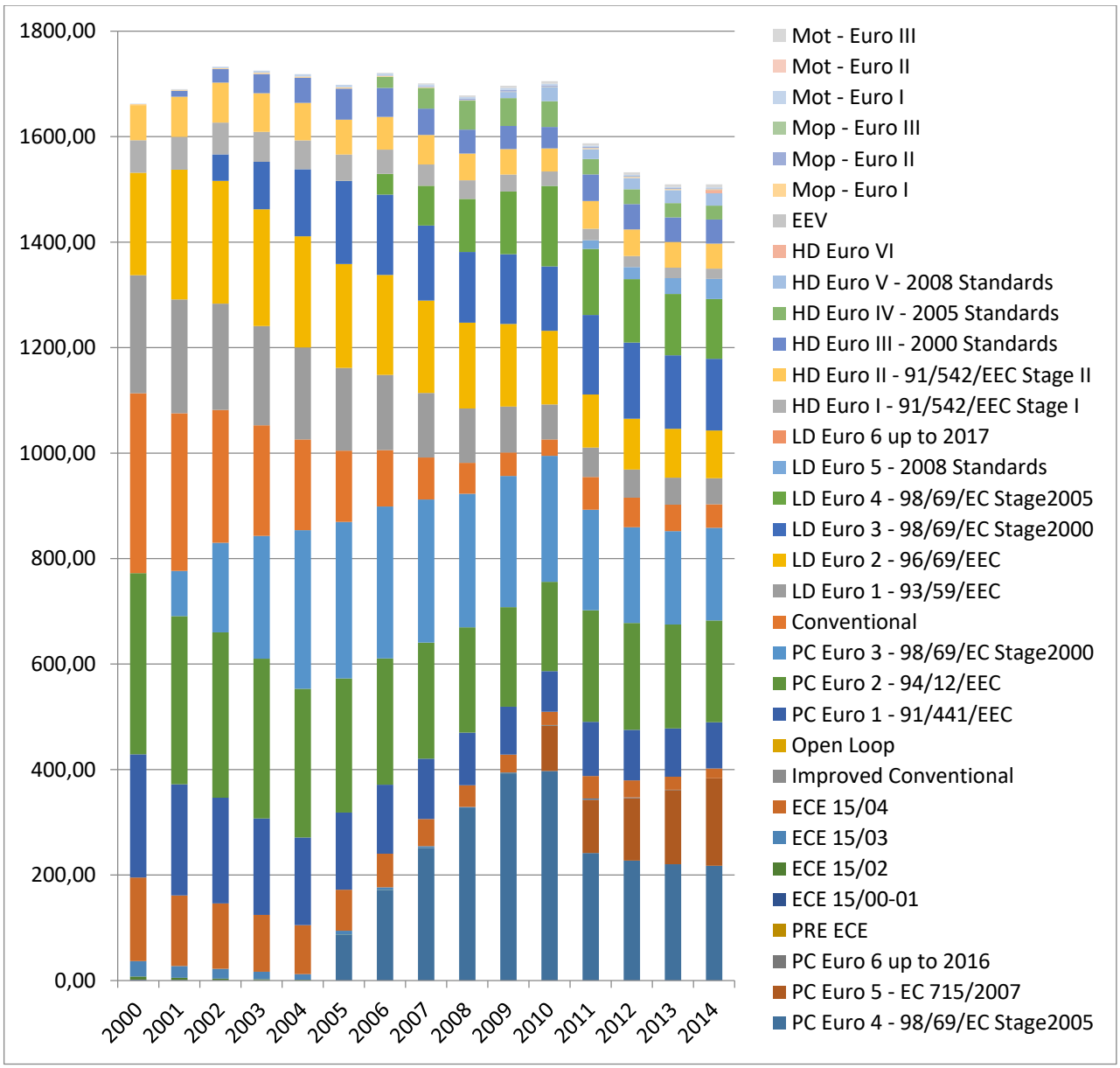

Figure 10. Total Costs of CO2 by technology in Million €.

In Figure 10, we can see the contribution of each technology in the CO2 annual emissions. The highest value was registered in 2002, reaching almost 1733M€. The total costs have been decreasing since 2011. The most contributing technologies are PC Euro 2, PC Euro 3, Conventional and PC Euro 4. The PC Euro 2 and Conventional contributions have been decreasing until 2011, where there was an augment around 25% and 100%, respectively, facing the values in 2010. Since then such values tend to decrease. Concerning PC Euro 3, we can see an increasing behavior until 2004 and since then, a decreasing tendency has been observed. In the period from 2005 to 2010, there was a considerable increasing, namely, an augment of almost 362%. In 2011, there was a reduction on costs with PC Euro 4 from 397,27M€ to 241,81M€.

3.4. Analysis of Costs by technology – NMVOC

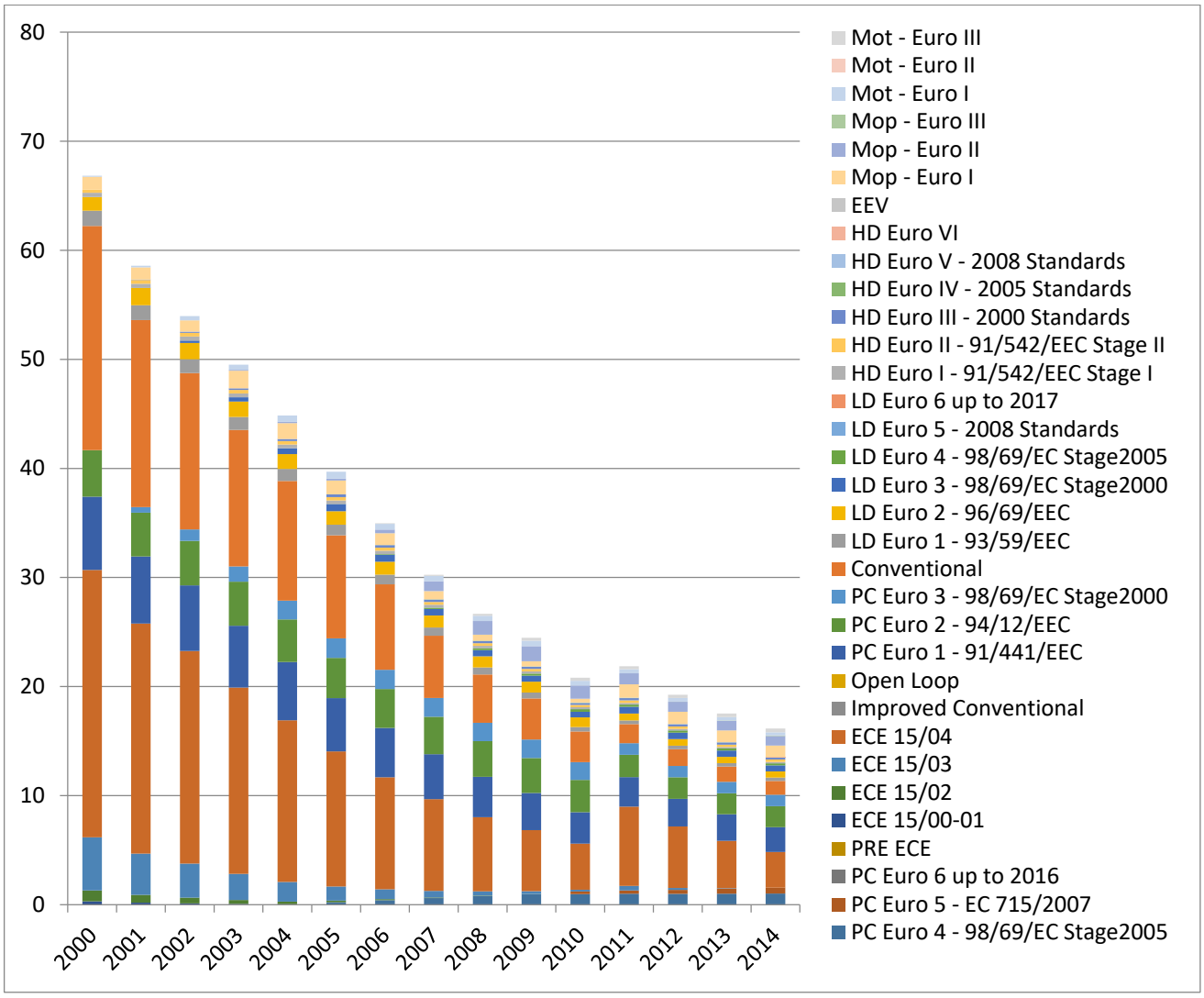

Figure 11. Total Costs of NMVOC by technology in Million €.

A first observation we can make from this figure is that there is a clear difference scenario, when compared to the previous case related to the annual costs with CO2 emissions. The highest value, 66,8M€, was registered in 2000. In particular, we can see that the costs with NMVOC emissions have been decreasing until 2010, presenting a reduction of almost 69% facing 2000. In 2011, such costs had a slight augment, around 1,05M€, but then, the costs have been decreasing, reaching 16,16M€ in 2014. The most contributing technologies for the decreasing tendency on the costs are ECE 15/04 and Conventional. The norm ECE 15/04 is the major responsible for the decreasing behavior, but is also the responsible for the increasing in costs in 2011. There can be observed that the costs with Conventional technology vehicles have been decreasing over the years.

3.5. Analysis of Costs by technology – NOX

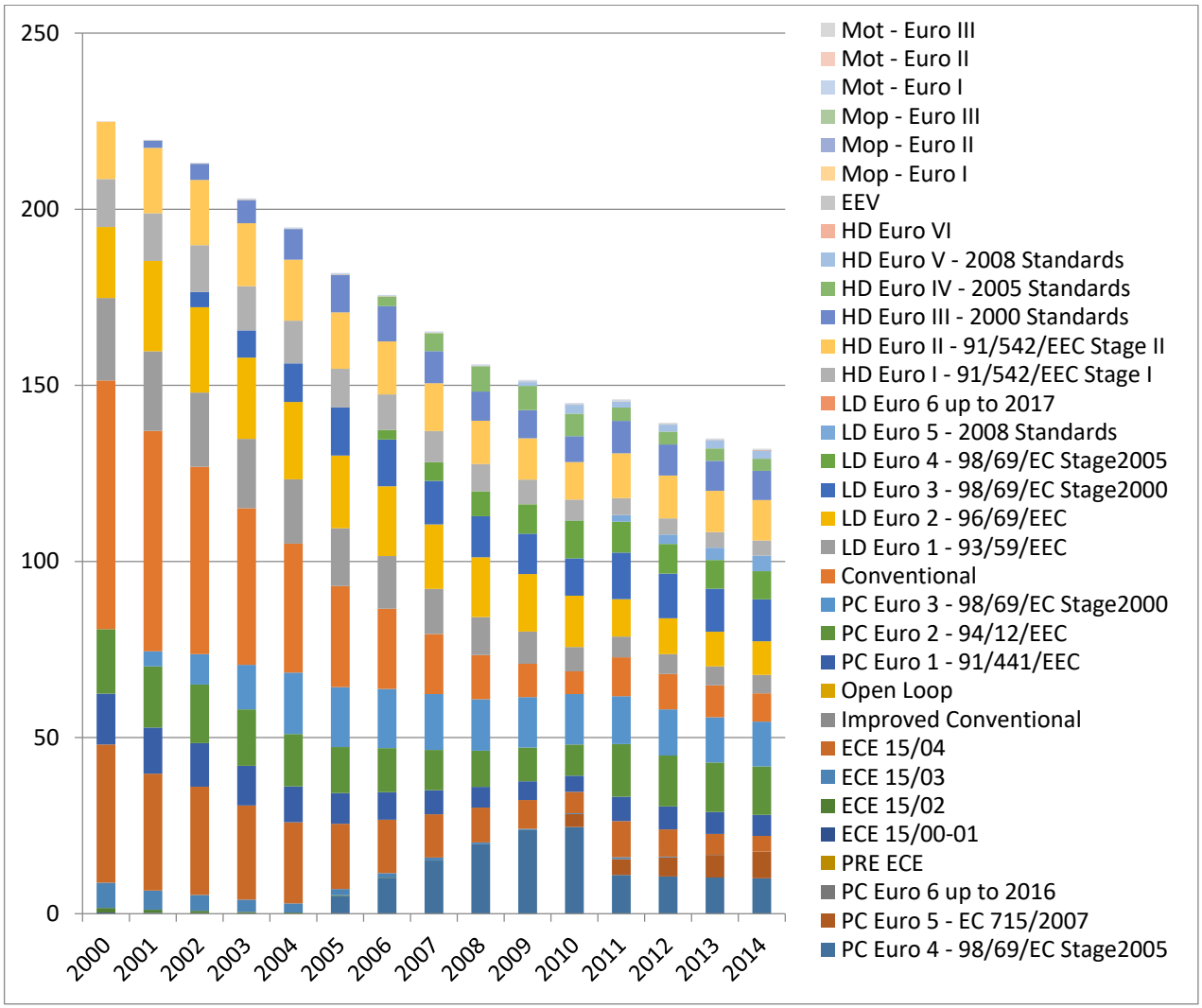

Figure 12. Total Costs of NOX by technology in Million €.

Similarly to the previous case, it can be observed a decreasing tendency in the costs until 2010. The reduction in this period is almost 36%. In 2011, there is a slight augment, and then it tends to decrease. In 2014, the costs with NOX emissions are around 132M€. The most contributing technologies for the decreasing tendency on the costs are Conventional and ECE-15/04. The costs with such technologies have been decreasing from 2000 to 2010, with reductions in the order of 64M€ and 33M€, respectively. Despite the reduction tendency of the costs with some technology vehicles, we can mention the increasing behavior of PC Euro 4 between 2005 and 2010.

3.6. Analysis of Costs by technology – PM 2.5

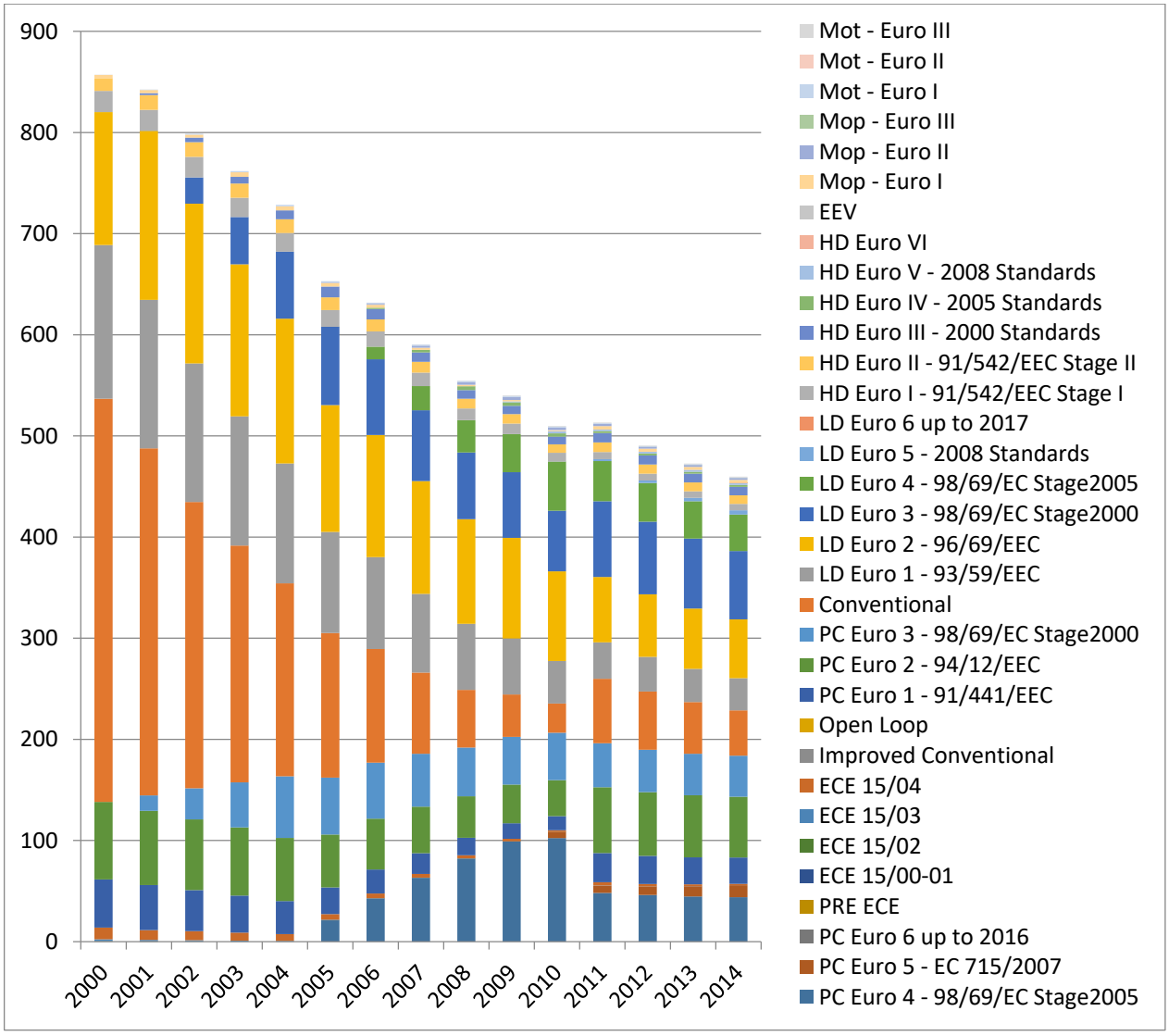

Figure 13. Total Costs of PM2.5 by technology in Million €.

The highest value is registered in 2000, ascending to more than 857M€. The decreasing tendency is clearly evident until 2010, with a reduction in the costs around 41%. There is a slight augment in 2011, but then it remains to decrease. In 2014, the costs are around 460M€. Regarding the most contributing vehicle technology, we can see that Conventional is by far the responsible for the decrease. The norm LD Euro 1 has also a key role, showing a decreasing behavior over the whole studied period. Once again, the costs with PC Euro 4 have been increasing between 2005 and 2010.

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