Technical paper 4

Estimation of pollutant emissions from road transport and costs in Spain

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PP1, PP6

1. Introduction

In 2014, transport sector in Spain was responsible for almost 82million of tonnes of CO2 emissions [4]. Many improvements have been implemented in vehicle technology and European Union (EU) has been introducing EURO standards in order to regulate vehicle emissions [1]. However, road transport is still an important source of air pollutants, being responsible for significant contributions to 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) emissions.

This study provides an analysis of major pollutant on-road emissions for all relevant road vehicle types from 2000 to 2014 based on Spain car fleet data. The report covers the emissions, related costs and considers the particular contribution of each vehicle category to the total of emissions.

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The report is organized as follows:

- The first section presents the methodology and data source used in the study.
- The second section provides an analysis of emissions on Spain, which make part of CISMOB project.

2. Methodology and data sources used

In order to estimate the total amount of pollutant emissions, COPERT v.4 [3] was used and the Spain-specific data covering the years from 2000 to 2014 was applied.

Analysis takes into account different types of vehicles, and is focused on assessing emissions of the following major pollutants: CO, CO2, VOC, NMVOC, NOX and PM2.5. Estimation of emissions of SO2 could not be concluded, since it relies on the annual fuel consumption and such information is not available in the dataset. The estimation of costs associated to the emissions of PM 2.5, NMVOC and NOX are based in the damage costs provided in € per tonne (2010) in [2]. Costs of CO2 emissions are based on the reference-value of 90€ per tonne [2].

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. Information on, for instance population, mileage in km/year, percentage of activity on urban, rural and highway areas, are available on the Spain purchased data.

We computed the emissions and then, calculated the associated costs per km of several pollutants.

3. Analysis of Spain 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 Spanish fleet.

	2000	2001	2002	2003	2004	2005	2006	2007
CO	1612637,16	1598911,11	1449004,97	1335136,92	1216263,05	1122083,29	1008247,90	907351,44
CO2	78259665,51	82181995,10	84299658,19	88320354,41	91485408,63	94397429,11	97010207,49	100553348,90
VOC	376685,61	366157,70	336647,16	311711,69	285256,64	264115,43	239186,22	218440,92
NMVOC	361807,45	351966,86	323605,31	299399,60	273865,37	253521,94	229593,16	209693,07
NOX	602628,39	621932,04	607872,94	622318,66	623556,78	608405,24	586083,52	581759,91
PM2.5	26722,91	29337,00	29043,17	29443,26	29588,78	28846,56	28270,94	27619,03

	2008	2009	2010	2011	2012	2013	2014
CO	787652,21	713032,45	635264,21	590756,60	554683,27	517840,22	474644,07
CO2	96088806,60	91404296,92	89302019,03	85957086,68	81628201,02	81424946,01	81425214,65
VOC	193311,16	175004,85	158919,15	150916,73	142342,73	133378,02	124002,30
NMVOC	185664,54	168022,17	152707,68	144573,85	136334,03	127708,83	118558,34
NOX	533313,35	489935,19	450627,08	451889,98	415956,67	406541,20	390487,05
PM2.5	25398,63	23382,75	21875,65	23288,49	21199,09	20504,11	18412,49

Table 2. Total emissions in Spain in tonnes.

The highest values on emissions are registered for CO2. Over the years, such values ascend, in average, to 88,3 million tonnes. The maximum value was registered in 2007 (around 10,06 million tonnes). In 2014, the value of CO2 emissions is almost 82 million tonnes. For CO2, it can be verified an increasing behaviour until 2007, and then a decreasing one. Considering the other pollutants, a closer look to the total amount of CO, VOC, NMVOC, NOX and PM2.5 emissions (Figure 1) shows that there has been a decreasing. In particular, comparing the values in 2000 and 2014, we can verify a reduction in the order of 62%.

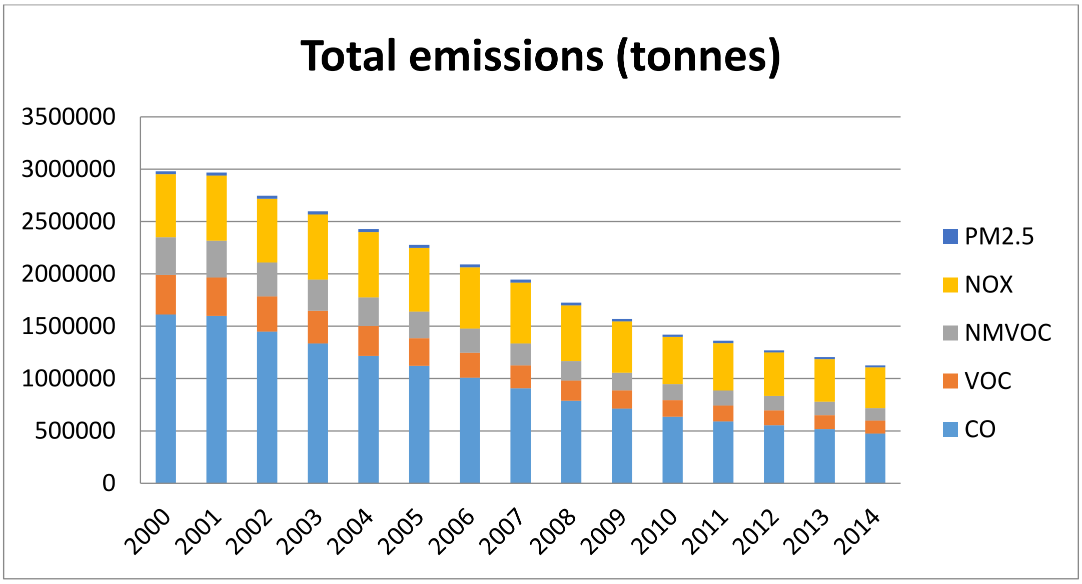

Figure 1. Total emissions of VOC, NMVOC, NOX and PM2.5 (tonnes).

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	7043,37	7396,38	7586,97	7948,83	8233,69	8495,77	8730,92	9049,80
NMVOC	410,65	399,48	367,29	339,82	310,84	287,75	260,59	238,00
NOX	2991,45	3087,27	3017,48	3089,19	3095,34	3020,12	2909,32	2887,86
PM2.5	2626,44	2902,05	2882,42	2903,61	2912,09	2863,37	2863,01	2812,64

	2008	2009	2010	2011	2012	2013	2014
CO2	8647,99	8226,39	8037,18	7736,14	7346,54	7328,25	7328,27
NMVOC	210,73	190,71	173,32	164,09	154,74	144,95	134,56
NOX	2647,37	2432,04	2236,91	2243,18	2064,81	2018,07	1938,38
PM2.5	2613,62	2417,88	2287,67	2486,08	2266,72	2193,78	1958,09

Table 3. Emission costs in Spain in Million €.

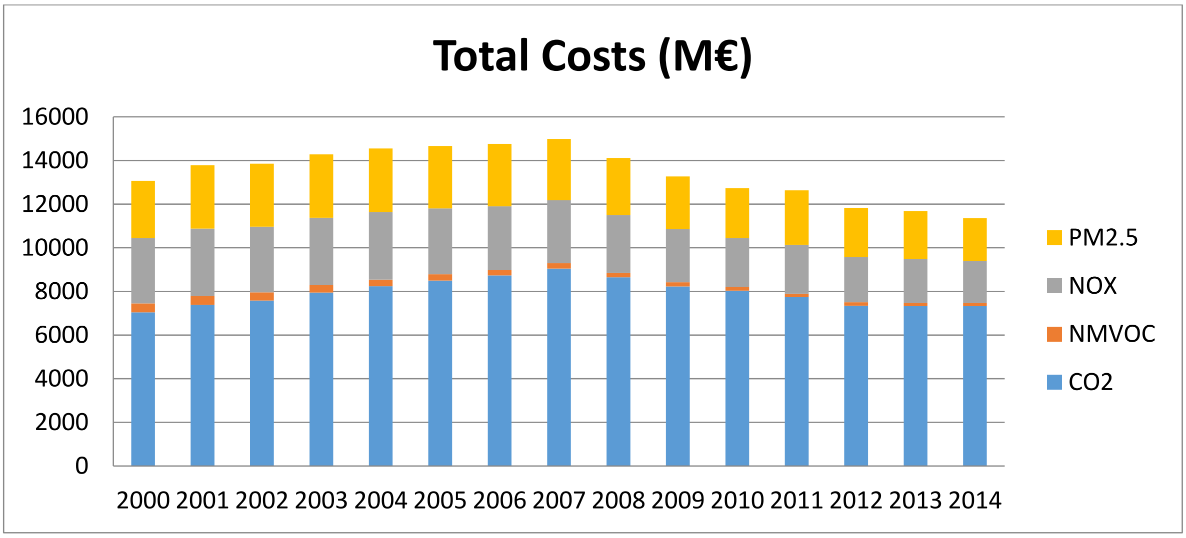

Figure 2. Total costs in Spain in Million €.

The costs with CO2 have been increasing until 2007, and then they slightly exhibit a decreasing tendency. Nevertheless, such costs are always above 7000M€. The costs with NOX and NMVOC have, in general, been decreasing over the years. The costs with PM 2.5 have been decreasing from 2004 until 2010. In 2011, such costs increased, and then, tend to decrease reaching 1958M€ in 2014. 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 around 13%.

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

	2000	2001	2002	2003	2004	2005	2006	2007
CO2	0,02518	0,02512	0,02470	0,02497	0,02485	0,02460	0,02418	0,02423
NMVOC	0,00147	0,00136	0,00120	0,00107	0,00094	0,00083	0,00072	0,00064
NOX	0,01069	0,01049	0,00982	0,00970	0,00934	0,00875	0,00806	0,00773
PM2.5	0,00939	0,00986	0,00939	0,00912	0,00879	0,00830	0,00793	0,00753

	2008	2009	2010	2011	2012	2013	2014
CO2	0,02394	0,02375	0,02321	0,02289	0,02271	0,02271	0,02266
NMVOC	0,00058	0,00055	0,00050	0,00049	0,00048	0,00045	0,00042
NOX	0,00733	0,00702	0,00646	0,00664	0,00638	0,00625	0,00600
PM2.5	0,00724	0,00698	0,00661	0,00736	0,00701	0,00680	0,00605

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

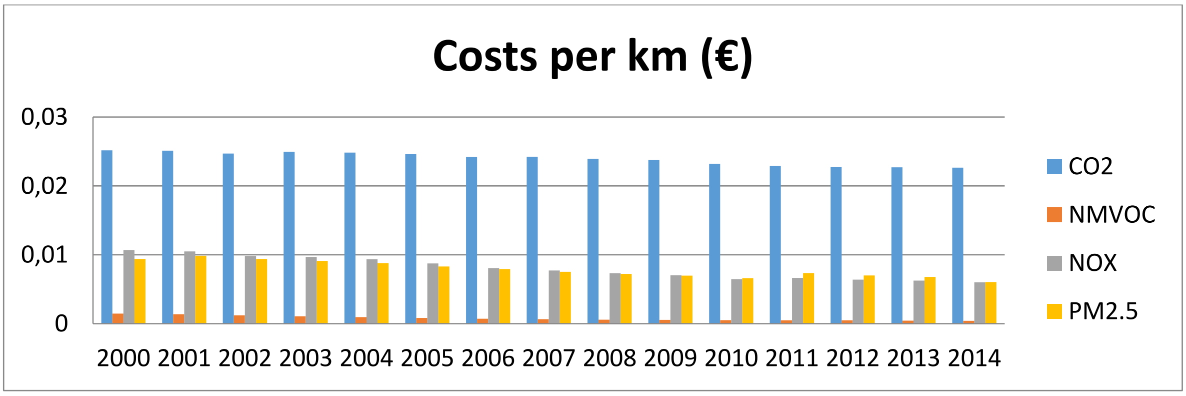

Figure 3. Costs per km (€).

It can be observed that in the studied period, the costs with CO2 present the highest values, always comfortably above 0,02€, while NMVOC presents the lowest. The costs with PM 2.5 and NOX are very similar over the years. The highest value of PM 2.5 was achieved in 2001 very close from below to 0,0099€, while the cost with NOX presents its maximum of approximately, 0,0107€ in 2000. We can see that the costs with PM 2.5 and NOX have, in general, been decreasing from 2001 to 2010, and in 2011 there was a slight augment, continuing after with a decreasing tendency. In 2014, the approximately cost per km of CO2 is 0,0227€, of NMVOC is 0,0004€, and the costs of NOX and PM 2.5 are around 0,0061€.

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.

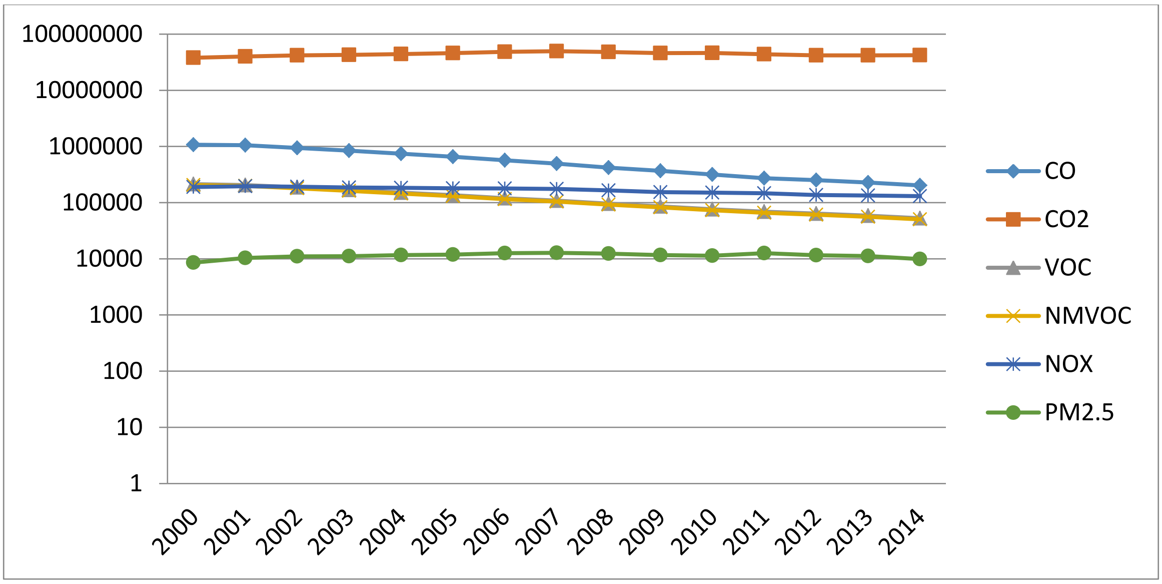

Figure 4. Passenger cars - annual emissions in tonnes (logarithmic scale).

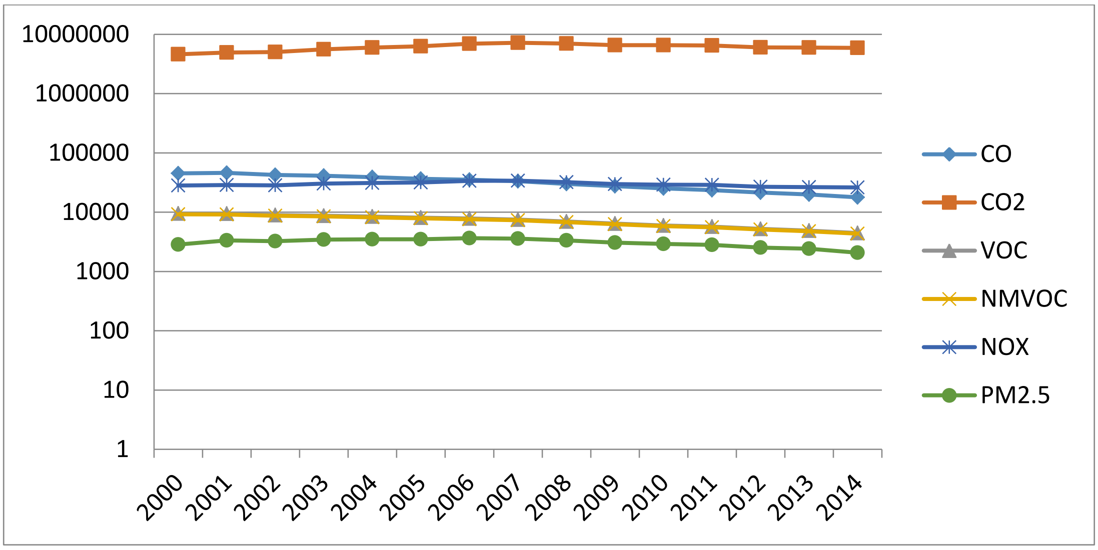

Figure 5. Light Commercial Vehicles – annual emissions in tonnes (logarithmic scale).

Regarding the emissions of pollutants by each type of vehicles, we can see from Figures 4 and 5 that the emissions of CO_2 for the passenger cars (PC) are, in average, around 44 million tonnes, while for light commercial vehicles (LCV), such value is approximately 6,1 million tonnes. For the LCV we can observe an increasing tendency until 2007, and then a decreasing. Considering the emissions of PM 2.5, we can see a decreasing tendency until 2007 for PC. After that, there were some variations in the behaviour. 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 27%. It can be observed that on both cases there is a decreasing tendency for CO, VOC and NMVOC emissions over the years. It can be observed that the emissions of CO are greater than NOX in the case of PC. Concerning the NOX emissions, we can observe a decreasing tendency in PC. But in the case of LCV, we can see that such values have been increasing until 2007, and then it tends to decrease.

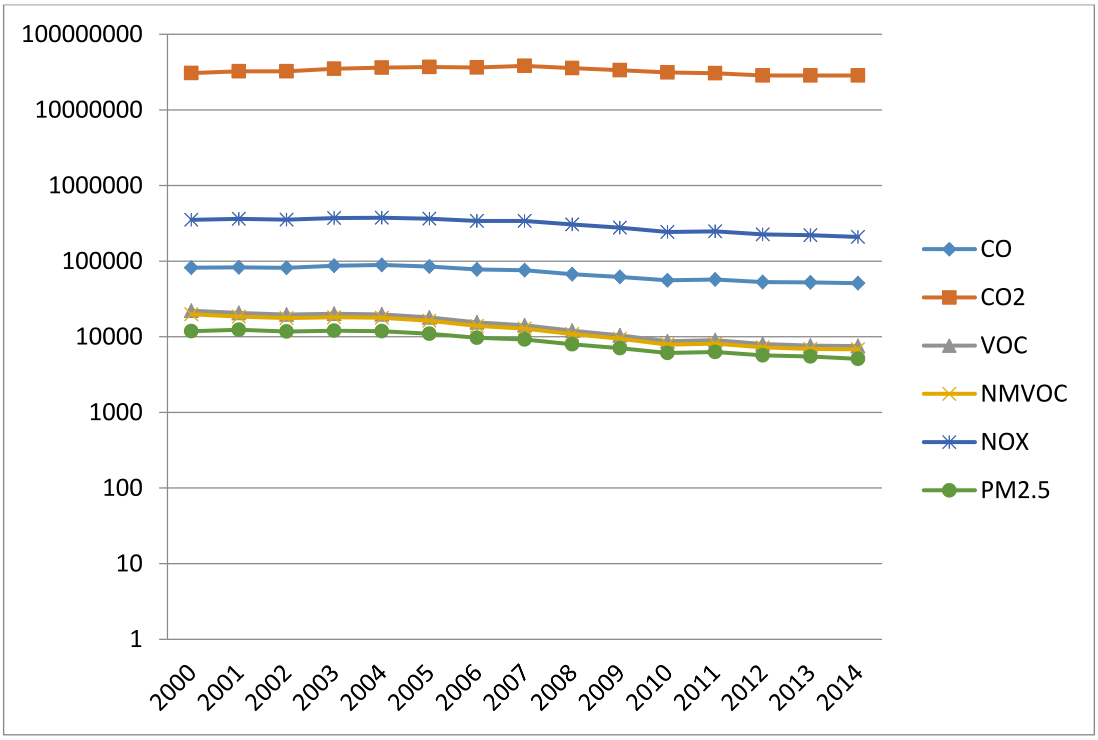

Figure 6. Heavy Duty Trucks - annual emissions in tonnes (logarithmic scale).

A first observation is that the emissions of NOX surpass those of CO. The CO2 emissions have been increasing until 2007, and then tend to decrease. Comparing the values between 2001 and 2014, there was a reduction of only 7%. For the pollutants CO, NOX, NMVOC, VOC and PM 2.5, it can be observed a decreasing behavior on all emissions from Heavy Duty Trucks since 2003.

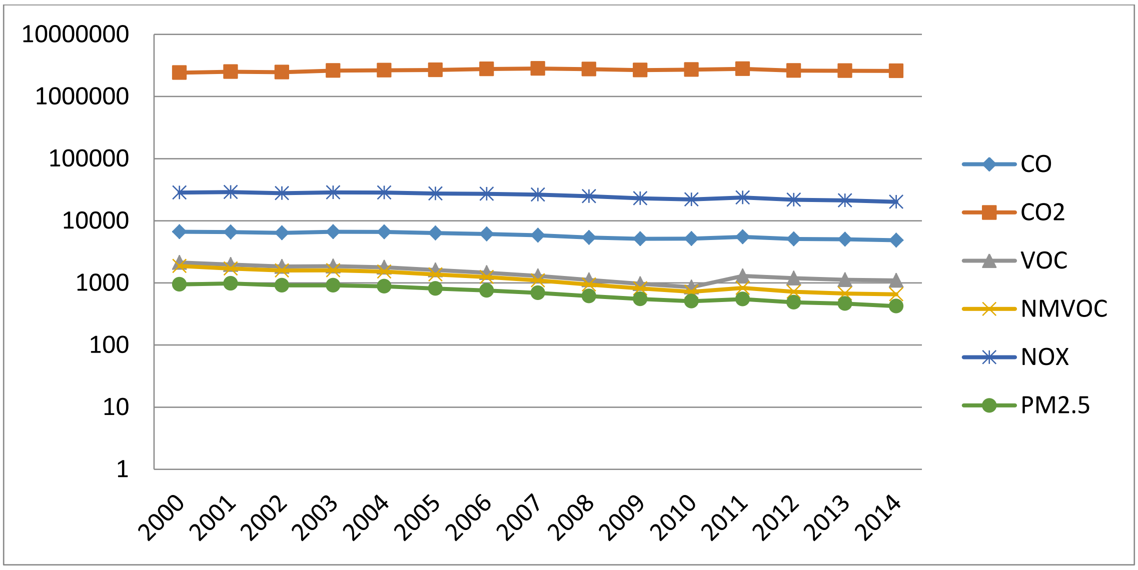

Figure 7. Buses - annual emissions in tonnes (logarithmic scale).

Concerning the buses fleet, the CO2 emissions have in general been stabilized in a ranging from 2,4 million tonnes up to 2,82. For the remaining pollutants, all of them present a decreasing tendency until 2011, where there was registered augments. 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 until 2010 is more pronounced on the emissions of PM 2.5, NMVOC and VOC.

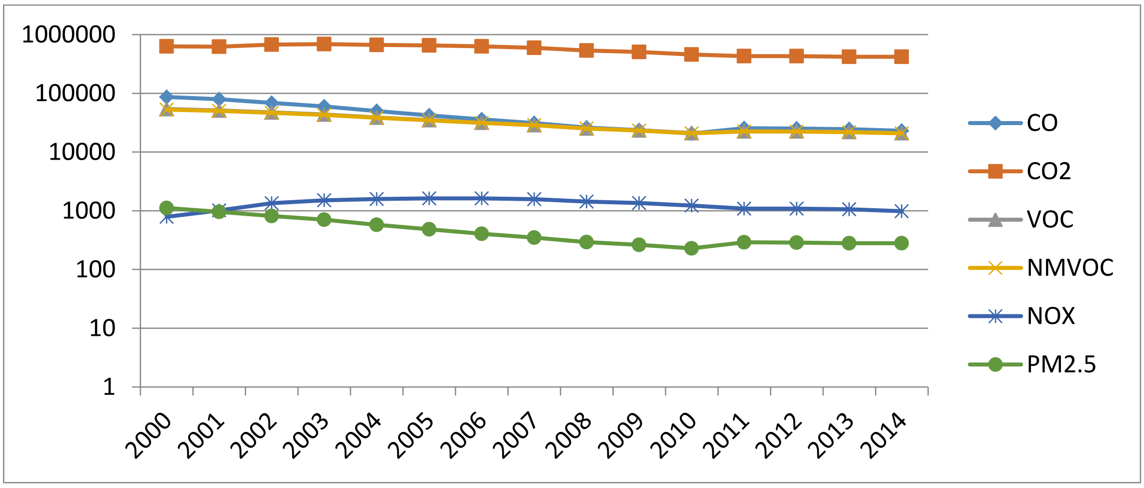

Figure 8. Mopeds – annual emissions in tonnes (logarithmic scale).

Since 2003, it can be observed a decreasing tendency in the emissions of CO2 of Mopeds. Concretely, comparing the highest and lowest values, achieved in 2003 and 2014, respectively, we can see a reduction of almost 39%. There was a considerable decreasing behavior until 2010 for the remaining pollutants, excepting for NOX, and then there was a slight augment and a tendency to stabilize the levels of emissions. The emission values of NOX have been increasing until 2005, and then tend to decrease. The highest value was around 1630tonnes, and the lowest was closer to 982tonnes, in 2014. Comparing the emissions of PM 2.5 between 2000 and 2014, we can verify a reduction in the order of 75%.

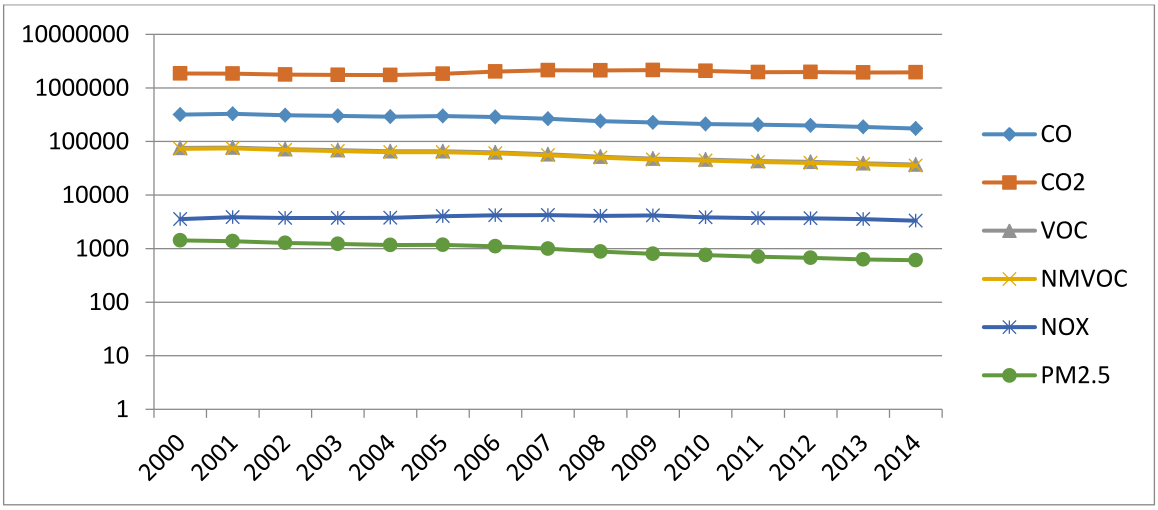

Figure 9. Motorcycles – annual emissions in tonnes (logarithmic scale).

Considering the CO2 emissions, we can see that the lowest value was registered in 2004, and is around 1,7million tonnes. The highest value is almost 2,2 million tonnes, registered in 2009. Since then, a decreasing tendency can be verified. With respect to the other pollutants, we can see a decreasing tendency of the emissions of CO, NMVOC, VOC and PM 2.5. The exception is for NOX, whose behavior has been varying from 3321 up to 4231tonnes. In average, there was 3827tonnes of NOX emissions in each year. Comparing the values of the emissions of PM 2.5 in the years 2000 and 2014 we can verify a reduction around 57%.

3.3. Analysis of Costs by technology – CO2

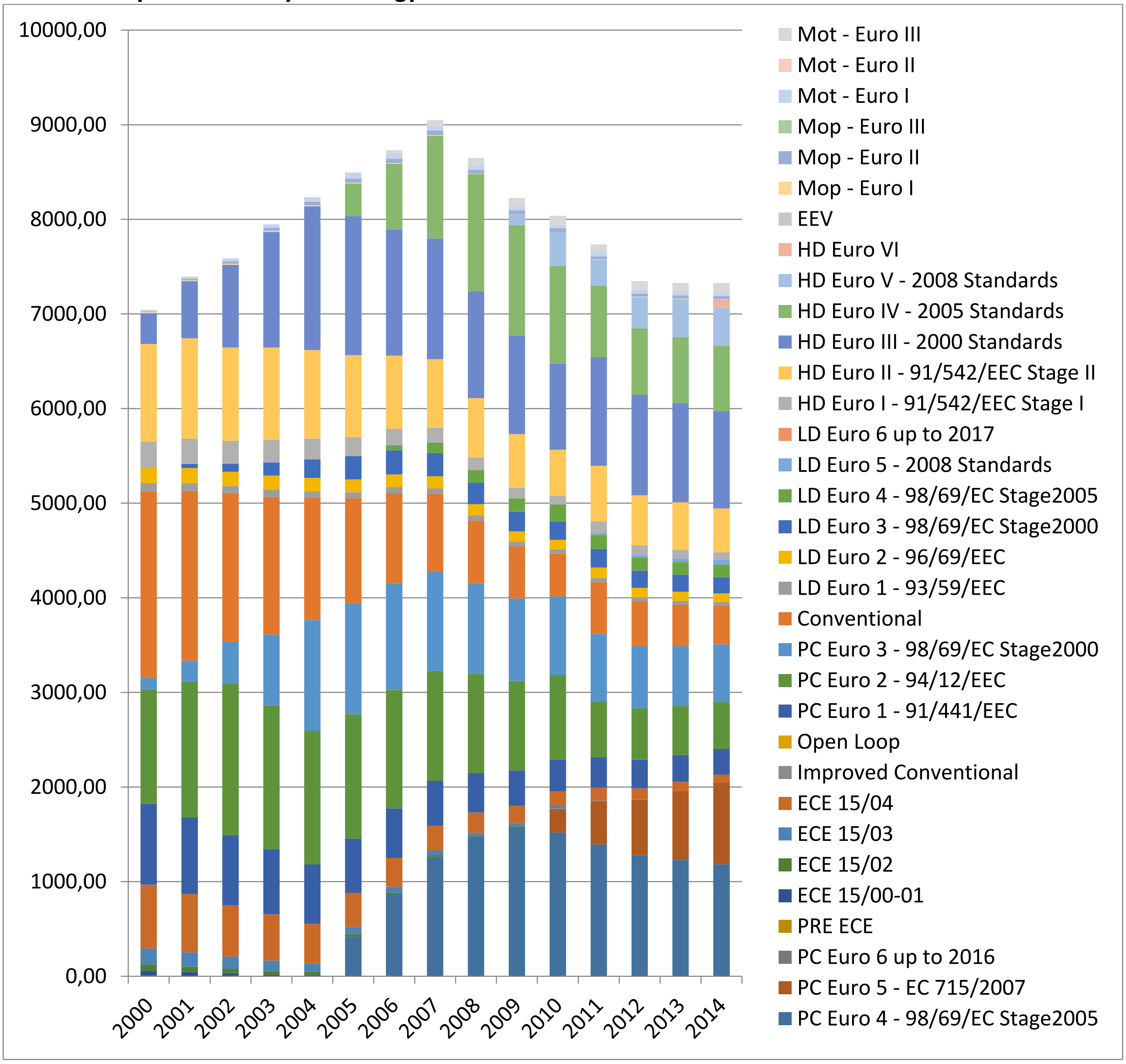

Figure 10. Total Costs of CO2 by technology in Million €.

This figure shows the contribution of each vehicle technology in the CO2 annual emissions. The first observation is that there was an increasing in costs until 2007, ascending to 9050M€. After, the costs tend to decrease until 2012. Since then, the total costs seem to stabilize around 7334M€. The most contributing technologies are PC Euro 4, PC Euro 2, Conventional and HD Euro III. Since 2002, the costs with PC Euro 2 have been decreasing, reaching almost 500M€ in 2014. In the Conventional case, the costs have been reducing over the years. It reduced at about 80%, comparing the values in 2000 with 2014. Concerning PC Euro 4, we can see an increasing behavior between 2005 and 2009, namely, an augment around 284%, and since then, a decreasing tendency.

3.4. Analysis of Costs by technology – NMVOC

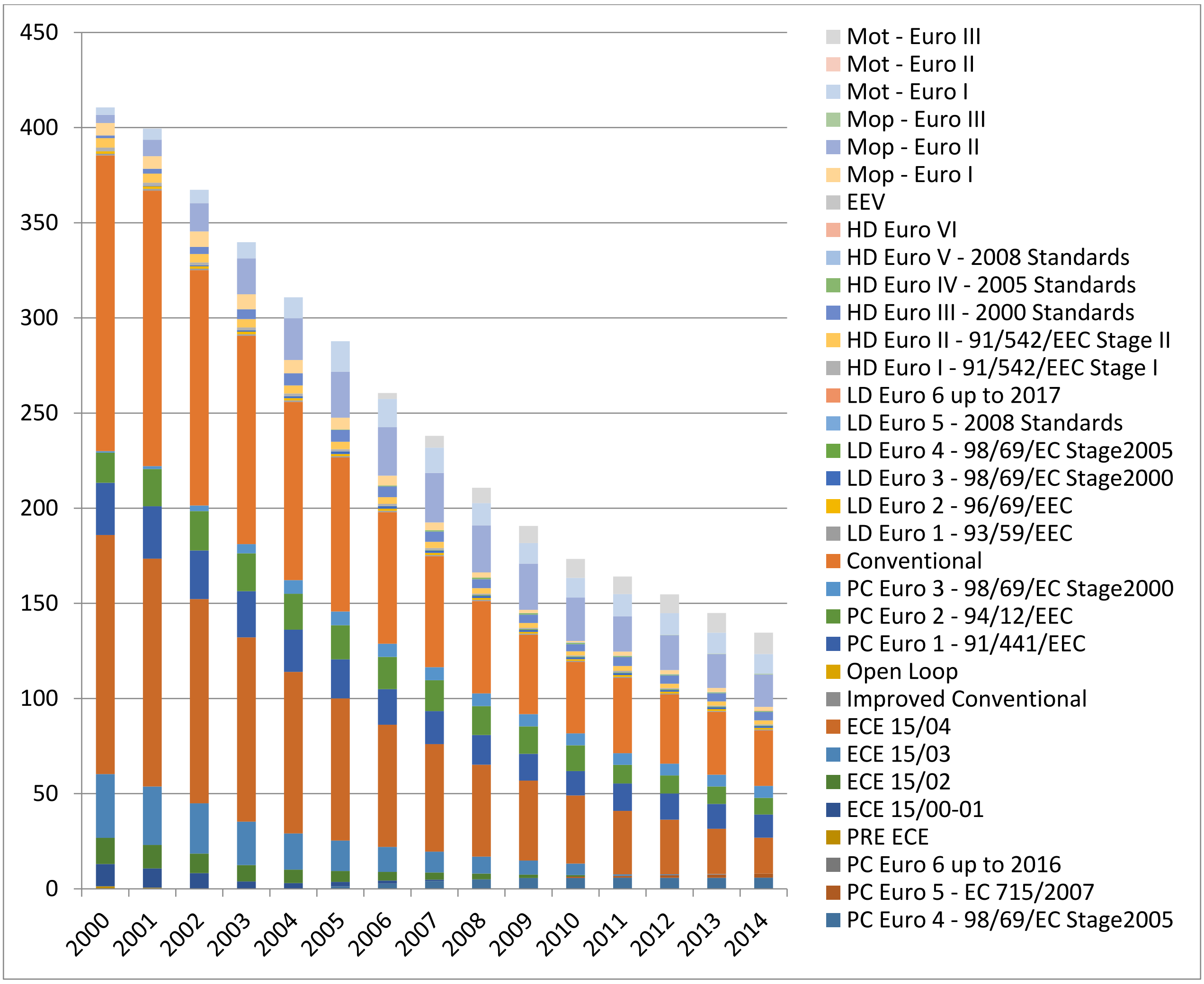

Figure 11. Total Costs of NMVOC by technology in Million €.

A first observation is that there is a clear tendency to decrease over the years. The highest value was approximately 411M€, and in 2014, the lowest value is around 135M€. This represents a reduction of 67% on the total costs with NMVOC emissions. The most contributing technologies for the decreasing tendency on the costs are clearly ECE 15/04 and Conventional. The norm Conventional is the major responsible for the decreasing tendency. Comparing the values in 2000 and 2014, we can verify a reduction of 81%. There can be observed that the costs with ECE 15/04 technology vehicles have also been decreasing over the years, with a reduction around 85%.

3.5. Analysis of Costs by technology – NOX

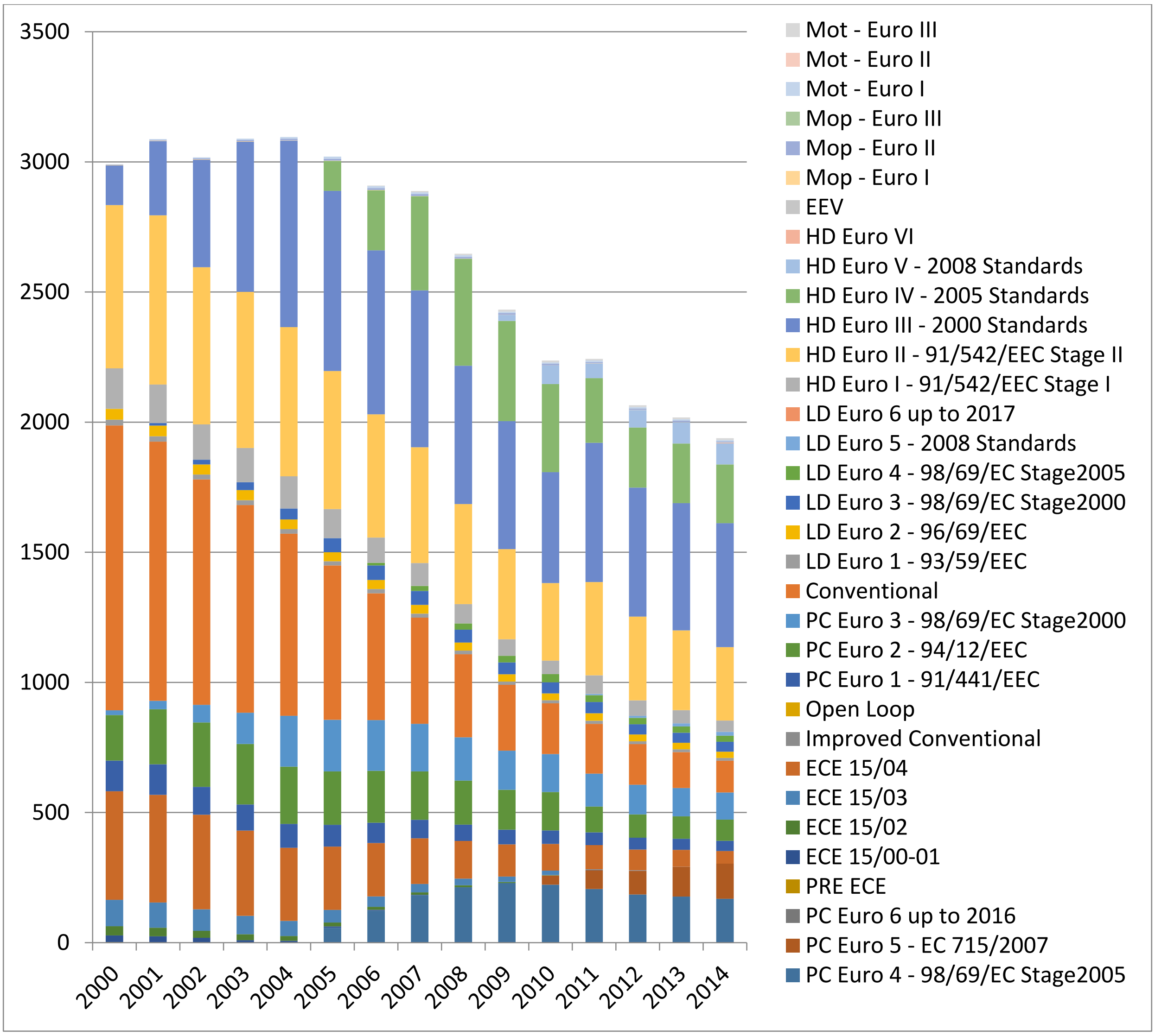

Figure 12. Total Costs of NOX by technology in Million €.

It can be observed an increase until 2004, where the maximum value, around 3095M€, is achieved, and then there is, in general, a decreasing tendency (except in 2011, where there was a slight increase). In 2014, the costs are around 1938M€. The most contributing technologies are Conventional, HD Euro II and HD Euro III. The costs with Conventional have been decreasing, with a reduction of almost 89%. With respect to the costs with HD Euro II we can observe that, in general, there was a decreasing behavior, reaching in 2010 almost 298M€. In 2011, such values increase up to 358M€, and then start to decrease. Until 2004, the costs with HD Euro III have been increasing, and since then they have been decreasing until 2010. In 2011, there was registered an augment of almost 26%. Similarly to the case of HD Euro II, the costs have been decreasing since 2011.

3.6. Analysis of Costs by technology – PM 2.5

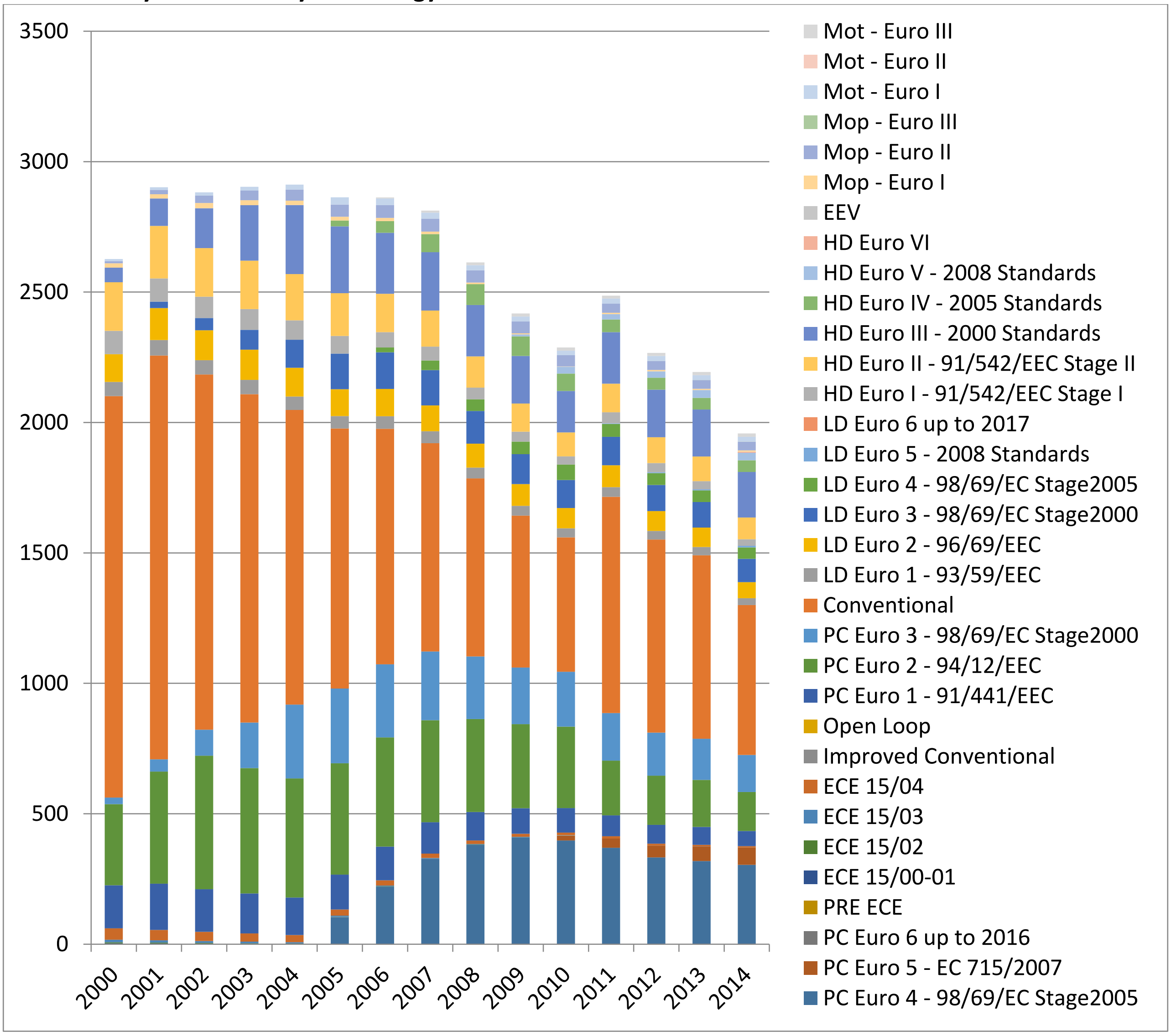

Figure 13. Total Costs of PM2.5 by technology in Million €.

It can be observed that the costs with PM 2.5 have been varying over the years, with a decreasing tendency between 2006 and 2010. The maximum value of approximately 2904M€ was achieved in 2003. In 2010, the costs reached 2288M€ and suffer an augment of almost 200M€. Since 2011, there is a decreasing tendency. In 2014 the total costs were approximately 1958M€. Regarding the most contributing vehicle technology, we can see that Conventional is by far the most contributing norm. The costs with such vehicles have been decreasing between 2001 and 2010. In 2011, the costs suffer an augment of almost 61%, facing the values in 2010. They have been decreasing since then. It can be mentioned that the PC Euro 2 is also responsible for the variation on the costs over the years, namely, the costs with such vehicles have been decreasing since 2002.

References

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