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Abstract
In the current technical report, we consider for the Greek road transport various policies of emission control for the period 2014-2030, and for the first time we estimate the related greenhouse gas emissions expressed in CO_2 equivalent and the total costs. These policies result from the high penetration rate of the most recent Euro standards (e.g. Euro 5,6) to the fleet of various vehicle classifications which will be in circulation at the end of each year for the specific period. For each vehicle classification, the shares of vehicles with different technology standards result from the continuation of 2000-2013 trends regarding the number of vehicles adjusted according to a conservative scenario of GDP growth after 2014. The vehicle classifications are differentiated according to (a) engine capacity for passenger cars and motorcycles-mopeds and maximum weight for trucks and buses, and (b) type of fuel (gasoline, diesel, liquefied petroleum gas). To calculate the greenhouse gas emissions, we adopt the Tier 2 method, which uses for each vehicle classification the number of vehicles, the annual average mileage per vehicle and the emission factors of each pollutant. For the calculation of total cost we consider four elements: capital, operation, maintenance and fuel costs. Having available the reductions in CO_2 emissions and the increases/decreases in the corresponding costs, marginal abatement cost curves are constructed first for specific vehicle classifications and second for general vehicle categories.

Keywords: Transport sector; passenger cars; tier 2 method; abatement costs; emissions.

JEL codes: Q50; Q53; Q54; Q58; M21; R40; C53.

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1. Introduction

According to the report by the Ministry of Environment, Energy and Climate Change (2013), for the transport sector, the largest share of greenhouse gas emissions (expressed in CO_2 equivalent) for the period 1990-2011 is attributed to road transport. According to that report this share had increased from 82% in 1990 to 87% in 2011. This increase was the result of two conflicting factors: (a) the large increase in the number of vehicles in Greece, and (b) the significant progress achieved in engine technologies for vehicle pollution control. These trends constitute the main reason for the current technical report to focus the analysis on road transport modes including passenger cars, light commercial vehicles, heavy duty trucks, urban buses, coaches, motorcycles and mopeds.

More specifically, in this report, we forecast greenhouse gas emissions expressed in CO_2 equivalent for the period 2014-2030 of various vehicle classifications differentiated each other according to technology (Euro 1, 2, 3, etc.. standards), fuel type (petrol, diesel, LPG), engine capacity for passenger cars and motorcycles-mopeds, and weight for trucks and buses. For each vehicle classification, the predictions are obtained based on data available for number of vehicles, annual distance (in kilometers) driven on average by the vehicles, emission factors and average fuel consumption (grams per kilometer). The data for the period 2000-2013 is available from EMISSIA SA[1].

Most importantly, to make these predictions we take into account the economic crisis in Greece, which had as a result the dramatic reduction of vehicle new registrations for the period 2010-2013. To remove the effect of the crisis, first we develop for the period 1985-2013 bivariate linear econometric models that relate the number of vehicles, (passenger cars,

[1] EMISSIA SA is an innovative company of the Aristotle University/Laboratory of Thermodynamics, which was founded in 2008 and specializes in emissions inventories and forecasts, emissions models, and studies for the impact of environmental policies. http://www.emisia.com

trucks, buses, motorcycles and mopeds) which were in circulation at the end of each year to the corresponding size of the gross domestic product (GDP) at current prices. Using the GDP forecasts for the period 2014-2030 from Halkos et al. (2014a), through the estimated regression models we proceed to forecast for each vehicle category the total number of vehicles in circulation at the end of each year for the specific period. Finally, the existing forecasts for the number of vehicles in each vehicle classification (which were obtained after fitting trend and double exponential smoothing models to the corresponding data of the period 2000-2013) are adjusted for each prediction year by using appropriate weights, as well as, the predicted total number of vehicles of each category from the estimated regression models.

Particularly important is also the part which refers to cost policies of emissions control for the period 2014-2030. These policies are related to the penetration rate of the emerging standards Euro 5, 6 (or alternatively V, VI for trucks) to the fleet of various vehicle classifications which will be in circulation at the end of each year for the period 2014-2030. So, different vehicle technology scenarios are defined according to the share of vehicles with these most recent technology standards in combination with the corresponding shares of older technologies. These shares are the result of the continuation of 2000-2013 trends (taking, however, into account the GDP growth from Halkos et al. 2014a) regarding the number of vehicles with the different standards in various classifications.

Finally, for the first time we give for the Greek road transport estimates of the total cost related to each vehicle technology scenario at 2013 prices first for the period 2000-2012 and then for the period 2013-2030. Finding out that in each year of the period 2000-2012 the share of the very recent Euro standards is rather small, while this share becomes high for each year between 2013 and 2030, the difference of the total cost between the two periods constitute an abatement cost. This is also justified by the fact that in the majority of vehicle classifications implying corresponding technology scenarios we observe decreases in greenhouse gas emissions between 2000-2012 and 2013-2030. This report closes by presenting two marginal abatement cost (MAC) curves, one for specific vehicle classifications and one for the general vehicle categories.

2. Statistics for various types of vehicles

The Hellenic Statistical Authority (EL.STAT)[2] gives definitions for the following categories of vehicles: Passenger cars, Buses, Trucks and Motorcycles. Definitions for what is considered as "new" or "used" vehicle are also provided. Through an exhaustive survey which uses the Registry of the Ministry of Infrastructure, Transport and Networks, EL.STAT gives the number of vehicles in each category (new plus used) which (a) are in circulation at the end of each year from 1985 onward (see Table A1 in Appendix) and (b) are released for the first time in Greece (see Table A2 in Appendix, new registrations). In Table A2, we also give for each vehicle category and for each year the number of erased-withdrawn vehicles and their share in the total number of vehicles in circulation at the end of each year. The number of erased-withdrawn vehicles in year t was calculated as the number of new registrations in year t minus the difference in the number of vehicles in circulation between years $t+1$ and t. From the survey of EL.STAT the following are excluded: Vehicles of Armed Forces, Police, Fire Brigade, State Services, Diplomatic Body, Foreign Missions, and Invalids of War, as well as, mopeds which are light two-wheel powered vehicles with an engine cylinder capacity not exceeding 50 cm^3, a maximum design speed not exceeding 45 km/h, a maximum continuous or net power $\leq$ 4000 W, and mass in running order $\leq$ 270 kg.

From the data of Tables A1 and A2, the following remarks are drawn:

[2] http://www.statistics.gr/portal/page/portal/ESYE/PAGE-themes?p_param=A1106

Passenger Cars: For the period 2007-2012 continuous decreases in the annual rates of growth are observed which lead after 2010 to continuous reductions in the total number of cars in circulation at the end of each year. Between 2007 and 2012, new registrations decreased by 80%, while in 2013 this reduction appears to recover. Finally, throughout the period 2000-2012 the share of withdrawn- erased cars ranges between 1,00% and 3,74% with an average of 2,24%.

Trucks: For the period 2007-2012 continuous decreases in the annual rates of growth are observed which lead after 2011 to continuous reductions in the total number of trucks in circulation at the end of each year. Between 2007 and 2012 new registrations decreased by 77%, while in 2013 this reduction appears to recover. Finally, throughout the period 2000-2012 the share of withdrawn- erased trucks ranges between 1,21% and 2,91% with an average of 1,86%.

Buses: For the period 2009-2012 continuous decreases in the annual rates of growth occur which lead after 2009 to continuous reductions in the total number of buses in circulation at the end of each year. Between 2009 and 2011, new registrations decreased by 76%, while throughout the period 2000-2012 the share of the withdrawn- erased buses ranges between 1,93% and 10,11% with an average of 5,09%.

Motorcycles: Although continuous increases in the number of motorcycles have occurred annually since 1985, between 2007 and 2012 the annual rates of growth are declined. New registrations decreased by 68% between 2007 and 2012, while throughout the period 2000-2012 the share of withdrawn- erased motorcycles ranges between −0,73% and 3,06%. Taking only the positive shares their average is 9,90%.

To determine using the Tier 2 method the total amount of Greenhouse Gases (Carbon dioxide, CO_2; Methane, CH_4; Nitrous oxide, N_2O), expressed in CO_2 equivalents, which are emitted by each vehicle category, it was necessary the availability of certain type of data (number of vehicles and annual average mileage) classified by (a) special characteristics of vehicles such as engine capacity for passenger cars and motorcycles, and maximum weight for trucks and buses, (b) type of fuel (gasoline, diesel, liquefied petroleum gas), and (c) technology expressed in Euro standards. Unfortunately neither EL.STAT nor EUROSTAT offer such data for Greece. But as mentioned in the introductory section of this report, this kind of data for the period 2000-2013 are available from EMISSIA SA. In particular, for Greece and for the period 2000-2013, Table 1 displays the vehicle classifications for which data are provided concerning (a) the number of vehicles in circulation at the end of each year, and (b) the annual distance in kilometers driven, on average, by each vehicle.

Regarding technology of vehicles, this is related to various standards, such as the recent Euro ones, offering various emission control systems. Since 1970, such systems have been introduced by relevant European Community Directives and regulations which vehicle manufacturers should comply with. In Table 2, for the vehicle categories being in circulation in Greece between 2000 and 2013, we give the list of emission control technologies expressed in terms of the corresponding emission legislation. Further details for the specifications of these technologies can be found in the report «*EMEP / EEA emission inventory guidebook 2013 update September 2014*».

For Passenger Cars, Trucks, Buses, and Motorcycles, Table A3 in Appendix displays the differences between the data reported by EL.STAT and EMISSIA SA concerning the total number of vehicles in circulation at the end of each year of the period 2000-2013. Following EL.STAT, for each vehicle category, using the weights calculated from EMISSIA SA data of each combination of vehicle classification/technology (see Tables 1 and 2), the number of vehicles in each combination was adjusted such that the sum in each year gives the total number of vehicles reported by EL.STAT for each vehicle category. These final numbers of vehicles for each combination will be used in the analysis which follows to estimate greenhouse gas emissions for the period 2014-2030.

Table 1: Vehicle classifications for which data concerning number of vehicles and annual average mileage are available for the Greek road transport

VEHICLE CATEGORY	CLASSIFICATIONS
PASSENGER CARS (PCs)	Gasoline 0,8 – 1,4 l Gasoline 1,4 – 2,0 l Gasoline > 2.0 l Diesel 1,4 – 2,0 l Diesel > 2.0 l Liquefied Petroleum Gas (LPG) Gasoline Hybrid Cars*
LIGHT COMMERCIAL VEHICLES (LCVs) WITH MAXIMUM WEIGHT ≤ 3,5 t	Gasoline Diesel
HEAVY DUTY TRUCKS (HDTs) WITH MAXIMUM WEIGHT ≤ 3,5 t	Gasoline Diesel, Rigid ≤ 7,5 t Diesel, Rigid 7,5 – 12 t Diesel, Rigid 12 – 14 t Diesel, Rigid 14 – 20 t Diesel, Rigid 20 – 26 t Diesel, Rigid 26 – 28 t Diesel, Rigid 28 – 32 t Diesel, Rigid > 32 t Diesel, Articulated 14 – 20 t Diesel, Articulated 20 – 28 t Diesel, Articulated 28 – 34 t Diesel, Articulated 34 – 40 t Diesel, Articulated 40 – 50 t Diesel, Articulated 50 – 60 t
URBAN BUSES	Diesel, midi ≤ 15 t Diesel, Standard 15 – 18 t Diesel, Articulated > 18 t
COACHES	Diesel, Standard ≤ 18 t
	Diesel, Articulated > 18 t
MOTORCYCLES	Gasoline, 4-stroke ≤ 250 cm^3 Gasoline, 4-stroke 250 – 750 cm^3 Gasoline, 4-stroke > 750 cm^3
MOPEDS**	2-stroke <50 cm^3

* The method of estimating the number of hybrid cars is described in Halkos et al. (2014b)
** Data for Mopeds are available only by EMISSIA SA.

Table 2: Vehicle technologies* for the Greek road transport

VEHICLE CATEGORY	LEGISLATION CLASSES
GASOLINE PASSENGER CARS	➢ Pre ECE vehicles up to 1971, ➢ ECE-15.00 and ECE 15.01 from 1972 until 1977, ➢ ECE-15.02 from 1978 until 1980, ➢ ECE-15.03 from 1981 until 1985, ➢ ECE-15.04 from 1985 until 1992, ➢ Euro 1 standard introduced by Directive 91/441/EEC, ➢ Euro 2 standard introduced by Directive 94/12/EC, ➢ Euro 3 standard introduced in January 2000 by Directive 98/69/EC – Stage 2000, ➢ Euro 4 standard introduced in January 2005 by Directive 98/69/EC – Stage 2005, ➢ Euro 5 standard introduced in May 2007 by Directive EC 715/2007 (this standard came into effect in January 2010 and for new type approvals in September 2009), and ➢ Euro 6 and 6c standards introduced in May 2007 by Directive EC 715/2007
DIESEL PASSENGER CARS	➢ Conventional class including (a) non-regulated cars launched prior to 1985 and (b) cars of pre-1992 production complying with Directive ECE 15/04 ➢ Euro 1 standard introduced by Directive 91/441/EEC ➢ Euro 2 standard introduced by Directive 94/12/EC ➢ Euro 3 standard introduced in January 2000 by Directive 98/69/EC – Stage 2000 ➢ Euro 4 standard introduced in January 2005 by Directive 98/69/EC – Stage 2005 ➢ Euro 5 standard introduced by Directive EC 715/2007 and was put in place in 2010 ➢ Euro 6 standard introduced by Directive EC 715/2007 (this standard will become effective for new types of cars in September 2014, with full implementation for all type approvals starting from January 2015) ➢ Euro 6c standard introduced by Directive EC 715/2007
LPG PASSENGER CARS	➢ Conventional class including all LPG cars complied with legislations prior to Directive 91/441/EEC ➢ Euro 1 standard introduced by Directive 91/441/EEC ➢ Euro 2 standard introduced by Directive 94/12/EC ➢ Euro 3 standard introduced in January 2000 by Directive 98/69/EC – Stage 2000 ➢ Euro 4 standard introduced in January 2005 by Directive 98/69/EC – Stage 2005 ➢ Euro 5 standard introduced by Directive EC 715/2007 ➢ Euro 6 standard introduced by Directive EC 715/2007
GASOLINE-HYBRID CARS	➢ Euro 4 class introduced by Directive 98/69/EC – Stage 2005
LIGHT COMMERCIAL VEHICLES (Gasoline and Diesel)	➢ Conventional Class including those vehicles covered by the various ECE steps up to 1993 ➢ Euro 1 standard introduced by Directive 93/59/EEC ➢ Euro 2 standard introduced by Directive 96/69/EEC ➢ Euro 3 standard introduced by Directive 96/69/EEC – Stage 2000 ➢ Euro 4 standard introduced by Directive 96/69/EEC – Stage 2005 ➢ Euro 5, 6, 6c standards introduced by Directive EC 715/2007
GASOLINE HEAVY-DUTY TRUCKS	Conventional class
DIESEL HEAVY DUTY TRUCKS, BUSES, AND COACHES	➢ Conventional including vehicles with engines complying with ECE 49 and earlier ➢ Euro I standard introduced by Directive 91/542/EEC – Stage I ➢ Euro II standard introduced by Directive 91/542/EEC – Stage II ➢ Euro III standard introduced by Directive 1999/96/EC – Stage I ➢ Euro IV standard introduced by Directive 1999/96/EC Step 2 – Stage II ➢ Euro V standard introduced by Directive 1999/96/EC final step – Stage III ➢ Euro VI standard introduced by Regulation EC 595/2009
FOUR-STROKE MOTORCYCLES	➢ Conventional class including all motorcycles complied with legislations prior to Directive 97/24/EC ➢ Mot – Euro I standard introduced by Directive 97/24/EC ➢ Mot – Euro II standard introduced by Directive 2002/51/EC stage I ➢ Mot – Euro III standard introduced by Directive 2002/51/EC stage II ➢ Mot – Euro IV and V standards introduced by Regulation 168/2013
TWO-STROKE MOPEDS	➢ Conventional class including all motorcycles complied with legislations prior to Directive 97/24/EC ➢ Mop – Euro I standard introduced by Directive 97/24/EC Stage I ➢ Mop – Euro I standard introduced by Directive 97/24/EC Stage II ➢ Mop – Euro III standard introduced by Directive 2002/51/EC ➢ Mop – Euro IV and V standards introduced by Regulation 168/2013

* Approximate implementation dates to all European Community (EC) Member states of the United Nations Economic Commission for Europe (UNECE) Regulation 15 amendments as regards the emissions of pollutants from vehicles lighter than 3,5 gross vehicle weight (GVW), «***EMEP / EEA emission inventory guidebook 2013 update September 2014***»

3. Forecasting the number of vehicles for the period 2014-2030

For each combination of vehicle classification/technology, we made forecasts for the number of vehicles in circulation at the end of each year for the period 2014-2030 using trend and double exponential smoothing models. The models were fitted to the available series of the period 2000-2013. The selected models which were eventually used to produce the forecasts for each combination are displayed in Tables A4-A8 of the Appendix for the various vehicle categories, namely, heavy duty trucks, light commercial vehicles, urban buses, coaches, motorcycles and mopeds. For passenger cars, the selected forecasting models are displayed in Table 3 of Halkos et al. (2014b). The selection of the most appropriate model between alternative trend (e.g. linear, quadratic, S-curve) and double exponential smoothing models was made by comparing the values of the statistical accuracy measures MAPE (Mean Absolute Percentage Error), MAD (Mean Absolute Deviation) and MSD (Mean Squared Deviation), in combination, however, with the reasonableness of the produced forecasts according to the time evolution of the number of vehicles between 2000 and 2013. The forecasting process was performed using the statistical package MINITAB.

An important problem arising in the forecasting process was the inclusion of the economic crisis impact on the numbers of vehicles being in circulation at the end of years from 2010 till 2013 and therefore on the annual forecasts for the period 2014-2030. From Table A2 of Appendix, we see that after 2007 new annual registrations for all vehicle categories dramatically decreased and this leaded to reductions in the number of vehicles in circulation between 2010 until 2013 for passenger cars, trucks and buses. To remove the effect of the crisis on the predicted number of vehicles for the period 2014-2030, for passenger cars, trucks, buses, motorcycles, and mopeds we developed different bivariate econometric models that related the number of vehicles in circulation at the end of each year to the GDP at current prices. The GDP series is available either by EL.STAT[3], or by the International Monetary Fund (IMF)[4]. Having available the forecasts of GDP growth according to a conservative scenario for the period 2014-2030 from Halkos et al. (2014a) *[the authors used the estimates of GDP growth for 2014 and 2015 according to the Organization of Economic Co-operation and Development (OECD, 2014)]*, and using appropriate econometric models we obtained forecasts for the total number of vehicles in circulation at the end of each year of this period. While for passenger cars the estimation process is described in Halkos et al. (2014b), the corresponding estimation process for the remaining vehicle categories is explained next.

3.1 Trucks and Motorcycles

To estimate the linear econometric model for trucks and motorcycles, we used initially as dependent variable the number of vehicles in circulation at the end of each year for the period 1985-2013 (see Table A1 of Appendix) and as explanatory the GDP at current prices for the same period. By applying augmented Dickey-Fuller tests (e.g., Box et al. 2008; Halkos 2011, 2006; Halkos and Kevork 2005; Harvey 1993) to both variables (number of vehicles and GDP), including in the test equation both a trend term and an intercept, we found out that the two series were stationary in second differences. However, applying the Engle-Granger test and testing the stationarity of the residuals from the linear regression of the number of vehicles on GDP (including in the test equation neither a trend term nor an intercept), we found out that we did not have sufficient statistical evidence to reject the null hypothesis that the residuals are not stationary in levels. Therefore, we concluded that the initial regressions were spurious and for each vehicle category the number of vehicles and GDP series were not cointegrated.

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[3] http://www.statistics.gr/portal/page/portal/ESYE/PAGE-themes?p_param=A0702

[4] http://www.imf.org/external/data.htm

An alternative approach was to use in the linear econometric model for each vehicle category as dependent variable the annual growth rate (namely, first differences) of the number of vehicles in circulation at the end of each year and as explanatory variable the annual growth rate of GDP. So, the following three variables were constructed:

($\Delta TRUCK_t$): Annual change in number of Trucks

($\Delta MOTO_t$): Annual change in number of Motorcycles

(ΔGDP_t): Annual growth rate of GDP

As it was expected, the application of the augmented Dickey-Fuller tests gave stationarity for these three new time series ($\Delta TRUCK_t$, $\Delta MOTO_t$, ΔGDP_t) in first differences. Moreover, applying the corresponding Engle-Granger test and testing for stationarity the residuals (including in the test equation neither a trend term nor an intercept) of the linear regressions (i) $\Delta TRUCK_t$ on ΔGDP_t, and (ii) $\Delta MOTO_t$ on ΔGDP_t, we found that at 10% significance level there was sufficient statistical evidence to reject the null hypothesis that the residuals are not stationary in levels. This offered the necessary information to support that the pairs of variables (i) $\Delta TRUCK_t$ and ΔGDP_t, (ii) $\Delta MOTO_t$ and ΔGDP_t are cointegrated. Performing also residual diagnostic tests in the two estimated regressions, we obtained sufficient statistical evidence to support that the errors are normally distributed with no ARCH effect. However, to both estimated regression models the errors were found to be serially correlated.

Following the above residual diagnostic test results, we proceeded to re-estimate the two linear regression models with the errors to be autocorrelated. Having strong indication from the sample ACF and PACF functions that the errors follow the first order autoregressive model, AR(1), the Cochranne-Orcutt method (e.g. Halkos, 2006, 2011) was used, which gave the following updated estimated models:

$$\Delta \hat{T}RUCK_t = 1096{,}686 + 1850{,}773 \cdot \Delta GDP_t + \hat{\varepsilon}_t$$

$$\text{where } \hat{\varepsilon}_t = 0{,}409643 \cdot \hat{\varepsilon}_{t-1} \text{ and } \hat{\varepsilon}_{2013} = -9547{,}904573 . \qquad (1)$$

$$\Delta\hat{MOTO}_t = 47750{,}361 + 1182{,}089 \cdot \Delta GDP_t + \hat{\varepsilon}_t$$

$$\text{where } \hat{\varepsilon}_t = 0{,}820655 \cdot \hat{\varepsilon}_{t-1} \text{ and } \hat{\varepsilon}_{2013} = -22240{,}031292.. \qquad (2)$$

Performing residual diagnostic tests in the estimated models (1) and (2) we obtained sufficient statistical evidence to support that the errors (a) are uncorrelated, (b) are normally distributed and (c) do not have ARCH effect. For the passenger cars the estimation process is described in Halkos et al. (2014b) where the corresponding estimated model is given in equation (1).

Substituting the forecasts of GDP changes according to the «OECD conservative scenario of GDP growth» from Halkos et al. (2014a) into the estimated models, we take for passenger cars, trucks and motorcycles the total number of vehicles at the end of each year of the period 2014-2030. For each vehicle category, this total number is given in columns (2), (4), and (6) of Table 3. Furthermore, in the same Table we give for each year [columns (3), (5), (7)] the estimated total numbers of passenger cars, trucks and motorcycles which are calculated as the sum of the individual forecasts obtained from the selected trend and double exponential smoothing models displayed in Table 3 of Halkos et al. (2014b) and in Tables A4 and A8 in the Appendix of this report.

From the data of Table 3 we confirm the negative impacts of the crisis from 2010 to 2013 on the predicted number of passenger cars, trucks and motorcycles in circulation during the period 2014-2030. More specifically, the estimated total numbers in columns (3), (5), (7), varies well below than the corresponding estimated numbers from the regressions models, especially for years close to 2030. This could be justified only by a «catastrophic scenario of negative GDP growth», which does not seem to be valid given the present conditions of the Greek economy. For this reason, we take as final forecasts for the number of vehicles in circulation the numbers presented in columns (2), (4), and (6) of Table 3. Then the individual forecasts which were made with the trend and double exponential smoothing models for the number of vehicles in each combination of classification/technology were readjusted appropriately such that their sum gives for each prediction year the total numbers given in columns (2), (4), and (6) of Table 3.

Table 3: Comparisons between forecasts for the total numbers of passenger cars, trucks and motorcycles in circulation at the end of each year

	Passenger Cars		Trucks		Motorcycles	
Year	From eq. (1) of Halkos et al. (2014b) (2)	From the models presented in Table 3 of Halkos et al. (2014b) (3)	From eq. (1) (4)	From the models presented in Tables A4, A5 (5)	From eq. (2) (6)	From the models presented in Table A8 (7)
2014	5.155.189	5.155.189	1.327.381	1.291.769	1.594.436	1.594.811
2015	5.229.007	5.160.988	1.346.004	1.263.989	1.628.690	1.605.873
2016	5.317.197	5.160.412	1.366.221	1.234.621	1.666.328	1.610.527
2017	5.415.059	5.155.710	1.387.255	1.209.128	1.706.634	1.608.470
2018	5.516.952	5.164.232	1.408.295	1.190.650	1.748.585	1.599.430
2019	5.623.377	5.186.007	1.429.617	1.181.265	1.792.254	1.581.753
2020	5.731.271	5.219.445	1.450.829	1.180.144	1.836.994	1.554.908
2021	5.841.511	5.261.949	1.472.199	1.185.748	1.882.893	1.520.168
2022	5.952.228	5.310.533	1.493.477	1.196.343	1.929.508	1.480.908
2023	6.064.240	5.362.293	1.514.863	1.210.339	1.976.911	1.442.063
2024	6.176.347	5.414.640	1.536.184	1.226.434	2.024.796	1.408.900
2025	6.289.225	5.465.428	1.557.585	1.243.634	2.073.220	1.385.573
2026	6.402.068	5.512.948	1.578.943	1.261.169	2.121.970	1.374.286
2027	6.515.398	5.555.884	1.600.361	1.278.483	2.171.090	1.375.264
2028	6.628.670	5.593.238	1.621.752	1.295.164	2.220.431	1.387.338
2029	6.742.282	5.624.265	1.643.191	1.310.901	2.270.030	1.408.664
2030	6.855.845	5.648.414	1.664.613	1.325.463	2.319.780	1.437.287

3.2 Buses

The application of augmented Dickey-Fuller tests to the levels of variables “Number of Buses” and “GDP” (including in the test equation both a trend term and an intercept) gave sufficient statistical evidence to support at 5% level of significance that the two series are stationary in second differences. Further, after the application of the Engle-Granger test and the testing for stationarity of the residuals from the estimation of the regression model

$$\mathrm{BUS}_t = \alpha + \beta \cdot \mathrm{GDP}_t + \gamma \cdot \mathrm{GDP}_t^2 + \varepsilon_t, \qquad (3)$$

including in the test equation neither a trend term nor an intercept, we obtained sufficient statistical evidence to conclude that this regression is not spurious. Performing also residual diagnostics tests on the residual series from the estimated regression of (3), we had sufficient statistical evidence to conclude that the errors are normally distributed with no ARCH effect. However, the sample ACF and PACF functions gave strong indications that the residuals are autocorrelated.

Fitting successfully an AR(2) process, $\varepsilon_t = \phi_1 \varepsilon_{t-1} + \phi_2 \varepsilon_{t-2} + u_t$, to the residuals of (3), we estimated the model

$$Y_t = \alpha^* + \beta \cdot X_t + \gamma \cdot Z_t + \varepsilon_t \tag{4}$$

where

$$Y_t = BUS_t - \hat{\phi}_1 BUS_{t-1} - \hat{\phi}_2 BUS_{t-2},$$

$$\alpha^* = \alpha \cdot \left(1 - \hat{\phi}_1 - \hat{\phi}_2\right),$$

$$X_t = GDP_t - \hat{\phi}_1 GDP_{t-1} - \hat{\phi}_2 GDP_{t-2},$$

$$Z_t = GDP_t^2 - \hat{\phi}_1 GDP_{t-1}^2 - \hat{\phi}_2 GDP_{t-2}^2,$$

with $\hat{\phi}_1 = 1{,}218280$ and $\hat{\phi}_2 = -0{,}660226$. Residual diagnostic tests applied to (4) gave sufficient statistical evidence to conclude that the errors (a) are uncorrelated, (b) are normally distributed and (c) do not have ARCH effect. Therefore, the total number of Buses in circulation at the end of each year of the period 2014-2030 will be estimated from

$$\hat{B}US_t = 17192{,}796 + 109{,}23629 \cdot GDP_t - 0{,}29384 \cdot GDP_t^2 + \hat{\varepsilon}_t,$$

where (5)

$$\hat{\varepsilon}_t = 1{,}218280 \cdot \hat{u}_{t-1} - 0{,}660226 \cdot \hat{u}_{t-2} \text{ with } \hat{\varepsilon}_{2012} = 366{,}6265 \text{ and } \hat{\varepsilon}_{2013} = 557{,}7319,$$

after substituting the forecasts of GDP according to the «OECD conservative scenario of GDP growth» from Halkos et al. (2014a). In Table 4, we present the estimated total number of Buses according to model (5). In the same Table we also give the total number of Buses which is calculated as the sum of the individual forecasts obtained from the selected trend and double exponential smoothing models presented in Tables A6 and A7 of the Appendix. These individual forecasts were adjusted appropriately such that for each year of the period 2014-2030 their sum gives the estimated total number computed from (5).

3.3 Mopeds

Unfortunately, the number of MOPEDS was not available by EL.STAT. So, to develop a prediction model based on GDP, we used the total number of MOPEDS which is given by EMISSIA SA. For the period 2000-2013, we found that the annual change of the number of MOPEDS ($\Delta MOPED_t$) is stationary in first differences. Performing the augmented Dickey-Fuller test (including in the test equation neither a trend term nor an intercept) on the residuals from the regression of $\Delta MOPED_t$ on ΔGDP_t we obtained sufficient statistical evidence to support at level of significance 1% that the series $\Delta MOPED_t$ and ΔGDP_t are co-integrated. Further, diagnostic tests on the residual series from the regression of $\Delta MOPED_t$ on ΔGDP_t indicated (although the sample is very small) that the errors are uncorrelated and display no ARCH effect. So, we decided to use the next model

$$\Delta \hat{MOPED}_t = 3968{,}0402 + 365{,}4959 \cdot \Delta GDP_t \qquad (6)$$

to predict the total number of Mopeds at the end of each year of the period 2014-2030, using for ΔGDP_t the forecasts for the annual GDP growth according to the «OECD conservative scenario of GDP growth» from Halkos et al. (2014a).

In Table 4 we present the estimated total number of Mopeds calculated from (6). In the same Table we also give the total number of Mopeds which is calculated as the sum of the individual forecasts obtained from the selected trend and double exponential smoothing models presented in Table A8 of the Appendix. Then these individual forecasts were adjusted appropriately such that for each year of the period 2014-2030 their sum gives the number computed from (6).

Table 4: Comparisons between forecasts for the total numbers of Buses and Mopeds in circulation at the end of each year

	Buses		Mopeds	
Year	From eq. (5)	From the models presented in Tables A6 and A7	From eq. (6)	From the models presented in Table A8
2014	26.894	26.742	237.679	201.410
2015	27.171	26.709	242.105	192.548
2016	27.429	26.737	246.747	184.261
2017	27.560	26.845	251.532	176.542
2018	27.550	27.016	256.267	169.369
2019	27.450	27.262	261.073	162.711
2020	27.333	27.571	265.834	156.525
2021	27.253	27.431	270.644	150.768
2022	27.228	27.496	275.422	145.390
2023	27.245	27.549	280.236	140.342
2024	27.274	27.599	285.027	135.578
2025	27.290	27.636	289.846	131.047
2026	27.280	27.656	294.649	126.705
2027	27.245	27.647	299.473	122.510
2028	27.197	27.593	304.287	118.418
2029	27.146	27.497	309.118	114.393
2030	27.100	27.333	313.943	110.399

Finally, we note that forecasts for the annual distance (in km) travelled on average by each vehicle were made for each combination of vehicle classification/technology. From the data of Emissia SA we found that the annual decreasing rate of the average distance traveled during the period 2000-2013 remained constant for each combination which uses the same type of fuel. So, we computed that for gasoline vehicles the annual average decreasing rate for the period 2000-2013 was 5,82%, for diesel vehicles 4,08% and for LPG passenger cars 2,17%. These three annual average reduction rates were used to predict for each combination the annual distance (in km) driven on average until 2030.

4. Greenhouse gas emissions from road transport

In road transport, greenhouse gases emitted by vehicle categories include Carbon dioxide (CO_2) from combustion of lubricant oil and from oxidation of fuel carbon, Methane (CH_4,) and Nitrous oxide (N_2O). To calculate the Greenhouse Gas emissions in the current study we adopt the Tier 2 method, which uses the number of vehicles, the annual average mileage per vehicle and the emission factors of each pollutant.

Particularly, for year t of period 2000-2030, let $E_{i,j,t}$ be the quantity of pollutant i emitted by the j combination of vehicle classification/technology, where i stands for CO_2 (from combustion of lubricant oil), CH_4, and N_2O. Then $E_{i,j,t}$ is computed from

$$E_{i,j,t} = N_{j,t} \times M_{j,t} \times EF_{i,j}, \tag{7}$$

where $N_{j,t}$ is the number of vehicles in combination j for year t, $M_{j,t}$ is the annual distance (in kilometers) driven on average by the vehicle in combination j for year t and $EF_{i,j}$ is the technology specific emission factor of pollutant i for the j combination of vehicle. The emission factors $EF_{i,j}$ in grams per kilometer for N_2O and CO_2 from combustion of lubricant oil are given in Tables 3.16, 3.18, 3.20, 3.22 and 3.24 of the report «EMEP/EEA emission inventory guidebook 2013 update September 2014». For Methane, $EF_{i,j}$ in mg/km was set equal to the Urban-Hot emission factor which is given in Table 3.72 of the same report. To transform CH_4 and N_2O emissions to CO_2 equivalent, we multiplied[5] one ton of methane by 21 and one ton of nitrous oxide by 310. Finally, the calculation of CO_2 emissions from the oxidation of fuel carbon was made according to equation (3) described in Halkos et al. (2014b).

Having available for each combination of vehicle classification/technology (see Tables 1 and 2) the number of vehicles (actual and predicted) which are in circulation at the end of each year of the period 2000-2030, various vehicle technology scenarios are specified according to the penetration rate from 2013 onwards of the emerging standards (e.g. Euro 5, 6) against old technologies (e.g. Conventional, Euro 1 up to Euro 4). For each scenario, in Table 5 we present the time evolution of shares of the emerging standards in combination with the corresponding shares of older standards. These shares are the result of the

[5] http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:CO2-eq

continuation of 2000-2013 trends regarding the number of vehicles adjusted according to «OECD conservative scenario of GDP growth» presented by Halkos et al. (2014a). Finally, for each vehicle scenario incorporated into the corresponding vehicle classification, we computed the total amount of greenhouse gas emissions expressed in CO_2 equivalents, first for period 2000-2012 and then for the period 2013-2030. The results are presented in Table 6 and in Figure 1.

The introduction of the most recent technology (e.g. Euro 4, 5, 6 etc) to the Greek vehicle fleet will have as result the reduction of CO_2 emissions between the periods 2000-2012 and 2013-2030 from 249,583 Mt to 228,016 Mt (-8,6%). For the two periods under consideration, the Passenger Cars are responsible for 38,4% of total emissions in the first period and for 41.3% of total emissions in the second period. The second most important source of CO_2 emissions are the Light Commercial Vehicles (with share 24,4% in 2000-2012 and 21,6% in 2013-2030), followed by the Heavy Duty Trucks (with 23,5% in the first period and 23,8% in the second period) and the Motorcycles-Mopeds (with 8,5% for both periods).

For the Passenger Cars (PCs) the most important sources of CO_2 emissions are the gasoline PCs with engine capacities 0,8-1,4l (with share 55,90% for the first period 2000-2012 and 42,40% for the second period 2013-2030) and 1,4-2l (with 35,94% for the first period and 28,02% for the second period 2013-2030). It is also expected that the diesel PCs with engine capacity less than 2l will be the third most important source of CO_2 emissions for the period 2013-2030 with share 17,68% compared to 2,73% of the first period 2000-2012. Between the two periods under consideration, we see reductions of CO_2 emitted by all the classifications of gasoline PCs ranging from -22,1% to -25,6%.

Table 5: Shares of recent Euro standards for vehicle classifications

Combinations of vehicle classification/technology		2000	2008	2013	2017	2020	2025	2030
Gasoline Passenger Cars								
0,8 – 1,4 l	*PRE ECE*	0,3%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
	ECE 15/00-01	3,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
	ECE 15/02	3,6%	0,3%	0,0%	0,0%	0,0%	0,0%	0,0%
	ECE 15/03	9,3%	2,6%	1,0%	0,4%	0,2%	0,1%	0,0%
	ECE 15/04	30,8%	15,9%	7,9%	3,1%	1,3%	0,3%	0,1%
	Euro 1	25,6%	17,5%	11,5%	5,3%	2,2%	0,4%	0,1%
	Euro 2	25,9%	28,3%	23,1%	19,2%	15,3%	8,2%	1,0%
	Euro 3	1,5%	29,6%	28,6%	27,0%	24,7%	20,2%	16,1%
	Euro 4	0,0%	5,8%	17,2%	22,8%	25,5%	25,8%	22,1%
	Euro 5, 6, 6c	0,0%	0,0%	10,7%	22,2%	30,9%	45,0%	60,7%
1,4 – 2,0 l	*PRE ECE*	0,2%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
	ECE 15/00-01	2,1%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
	ECE 15/02	2,8%	0,1%	0,0%	0,0%	0,0%	0,0%	0,0%
	ECE 15/03	7,6%	1,2%	0,5%	0,2%	0,1%	0,0%	0,0%
	ECE 15/04	26,7%	8,8%	3,8%	1,6%	0,8%	0,2%	0,0%
	Euro 1	31,2%	15,8%	9,9%	4,7%	2,2%	0,5%	0,1%
	Euro 2	27,8%	24,5%	19,0%	10,9%	5,4%	1,2%	0,2%
	Euro 3	1,7%	40,5%	38,2%	35,5%	32,7%	25,9%	19,2%
	Euro 4	0,0%	9,1%	19,5%	28,1%	32,2%	33,9%	31,1%
	Euro 5, 6, 6c	0,0%	0,0%	9,2%	19,0%	26,7%	38,3%	49,3%
> 2 l	*PRE ECE*	1,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
	ECE 15/00-01	5,2%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
	ECE 15/02	4,4%	0,8%	0,0%	0,0%	0,0%	0,0%	0,0%
	ECE 15/03	8,1%	1,6%	0,6%	0,0%	0,0%	0,0%	0,0%
	ECE 15/04	14,7%	3,1%	2,2%	1,9%	1,6%	1,1%	0,6%
	Euro 1	39,3%	8,9%	6,4%	5,6%	5,0%	3,9%	2,9%
	Euro 2	26,7%	12,9%	9,6%	9,2%	9,1%	9,5%	10,5%
	Euro 3	0,7%	54,8%	48,4%	41,6%	36,6%	28,6%	20,2%
	Euro 4	0,0%	17,9%	25,9%	28,6%	29,3%	28,5%	24,5%
	Euro 5, 6, 6c	0,0%	0,0%	6,9%	13,2%	18,4%	28,3%	41,3%
Diesel Passenger Cars								
0,8 – 1,4 l	*Euro 5, 6, 6c*	0,0%	0,0%	0,0%	100,0%	100,0%	100,0%	100,0%
1,4 – 2,0 l	*Conventional*	43,5%	3,4%	0,1%	0,0%	0,0%	0,0%	0,0%
	Euro 1	32,5%	19,7%	3,5%	0,4%	0,1%	0,0%	0,0%
	Euro 2	24,0%	17,6%	3,3%	0,4%	0,1%	0,0%	0,0%
	Euro 3	0,0%	51,6%	29,9%	14,9%	12,1%	8,8%	6,2%
	Euro 4	0,0%	7,7%	34,9%	17,9%	17,7%	17,6%	17,7%
	Euro 5, 6, 6c	0,0%	0,0%	28,3%	66,4%	69,9%	73,6%	76,1%
> 2 l	Conventional	39,6%	1,2%	0,0%	0,0%	0,0%	0,0%	0,0%
	Euro 1	35,8%	15,8%	1,6%	0,2%	0,1%	0,0%	0,0%
	Euro 2	24,6%	13,2%	1,4%	0,2%	0,0%	0,0%	0,0%
	Euro 3	0,0%	58,5%	41,6%	31,5%	24,8%	17,4%	12,8%
	Euro 4	0,0%	11,3%	33,6%	35,9%	38,1%	40,4%	41,8%
	Euro 5, 6, 6c	0,0%	0,0%	21,7%	32,1%	37,0%	42,1%	45,4%

Table 5 (continued)

Combinations of vehicle classification/technology		2000	2008	2013	2017	2020	2025	2030
LPG Passenger Cars	*Conventional*	51,7%	0,1%	0,0%	0,0%	0,0%	0,0%	0,0%
	Euro 1	16,3%	1,0%	0,0%	0,0%	0,0%	0,0%	0,0%
	Euro 2	32,0%	17,2%	0,2%	0,0%	0,0%	0,0%	0,0%
	Euro 3	0,0%	68,9%	37,5%	11,8%	4,6%	0,9%	0,2%
	Euro 4	0,0%	12,8%	37,7%	48,8%	51,0%	51,2%	50,6%
	Euro 5, 6	0,0%	0,0%	24,6%	39,4%	44,5%	47,9%	49,2%
Gasoline Hybrid Cars	*Euro 4, 5, 6*	0,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Light Commercial Vehicles <3,5 t								
Gasoline	Conventional	79,5%	68,4%	50,3%	24,1%	8,4%	0,9%	0,1%
	Euro 1	14,3%	14,6%	11,7%	8,9%	5,5%	1,4%	0,3%
	Euro 2	6,1%	7,1%	5,7%	4,3%	2,7%	0,7%	0,1%
	Euro 3	0,0%	8,3%	9,9%	9,6%	8,6%	5,8%	3,7%
	Euro 4	0,0%	1,7%	13,0%	25,7%	33,0%	34,5%	30,0%
	Euro 5, 6, 6c	0,0%	0,0%	9,5%	27,4%	41,9%	56,7%	65,8%
Diesel	Conventional	54,8%	19,8%	11,9%	8,7%	7,0%	5,1%	4,0%
	Euro 1	12,4%	4,8%	3,0%	2,3%	1,9%	1,4%	1,1%
	Euro 2	32,8%	17,3%	12,3%	10,5%	9,4%	8,3%	7,7%
	Euro 3	0,0%	44,2%	41,4%	32,1%	26,0%	16,7%	8,1%
	Euro 4	0,0%	14,0%	23,2%	27,9%	30,0%	31,0%	29,4%
	Euro 5, 6, 6c	0,0%	0,0%	8,1%	18,4%	25,7%	37,5%	49,7%
Heavy Duty Trucks								
Gasoline	*Conventional*	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Diesel, Rigid <= 7,5 t	*Conventional*	55,2%	30,0%	22,4%	16,8%	12,8%	7,8%	4,5%
	Euro I	23,2%	13,3%	10,7%	8,5%	6,8%	4,1%	1,2%
	Euro II	21,6%	21,8%	17,6%	16,1%	15,4%	14,7%	14,7%
	Euro III	0,0%	24,8%	20,0%	16,4%	13,8%	9,4%	4,8%
	Euro IV	0,0%	10,1%	18,5%	23,9%	26,6%	28,3%	26,5%
	Euro V, VI	0,0%	0,0%	10,6%	18,3%	24,6%	35,8%	48,4%
Diesel, Rigid 7,5 – 12 t	*Conventional*	55,2%	30,0%	22,4%	16,8%	12,8%	7,8%	4,5%
	Euro I	23,2%	13,3%	10,7%	8,5%	6,8%	4,1%	1,2%
	Euro II	21,6%	21,8%	17,6%	16,1%	15,4%	14,7%	14,7%
	Euro III	0,0%	24,8%	20,0%	16,4%	13,8%	9,4%	4,8%
	Euro IV	0,0%	10,1%	18,5%	23,9%	26,6%	28,3%	26,4%
	Euro V, VI	0,0%	0,0%	10,6%	18,3%	24,6%	35,8%	48,4%
Diesel, Rigid 12 – 14 t	*Conventional*	55,2%	30,0%	22,4%	16,8%	12,8%	7,8%	4,5%
	Euro I	23,2%	13,3%	10,7%	8,5%	6,8%	4,1%	1,2%
	Euro II	21,6%	21,8%	17,6%	16,1%	15,4%	14,7%	14,7%
	Euro III	0,0%	24,8%	20,0%	16,4%	13,8%	9,3%	4,8%
	Euro IV	0,0%	10,2%	18,5%	23,9%	26,6%	28,3%	26,5%
	Euro V, VI	0,0%	0,0%	10,6%	18,3%	24,6%	35,8%	48,4%
Diesel, Rigid 14 – 20 t	*Conventional*	55,2%	30,0%	22,4%	16,8%	12,8%	7,8%	4,5%
	Euro I	23,2%	13,3%	10,7%	8,5%	6,8%	4,1%	1,2%
	Euro II	21,6%	21,8%	17,6%	16,1%	15,4%	14,8%	14,7%
	Euro III	0,0%	24,8%	20,0%	16,4%	13,8%	9,4%	4,8%
	Euro IV	0,0%	10,2%	18,5%	23,9%	26,5%	28,2%	26,3%
	Euro V, VI	0,0%	0,0%	10,6%	18,3%	24,6%	35,8%	48,4%

Table 5 (continued)

Combinations of vehicle classification/technology		2000	2008	2013	2017	2020	2025	2030
Heavy Duty Trucks								
Diesel, Rigid 20 – 26 t	*Conventional*	55,2%	30,0%	22,4%	16,8%	12,8%	7,8%	4,5%
	Euro I	23,2%	13,3%	10,7%	8,5%	6,8%	4,1%	1,2%
	Euro II	21,6%	21,8%	17,6%	16,1%	15,4%	14,7%	14,7%
	Euro III	0,0%	24,8%	20,0%	16,4%	13,8%	9,4%	4,8%
	Euro IV	0,0%	10,2%	18,5%	23,9%	26,6%	28,3%	26,5%
	Euro V, VI	0,0%	0,0%	10,6%	18,3%	24,6%	35,7%	48,3%
Diesel, Rigid 26 – 28 t	*Conventional*	55,0%	29,6%	22,5%	16,5%	12,5%	7,4%	4,3%
	Euro I	23,3%	13,6%	11,3%	8,8%	6,3%	4,3%	1,1%
	Euro II	21,7%	22,2%	17,5%	16,5%	15,6%	16,0%	15,2%
	Euro III	0,0%	24,7%	20,0%	16,5%	12,5%	7,4%	3,3%
	Euro IV	0,0%	9,9%	17,5%	23,1%	27,1%	27,7%	27,2%
	Euro V, VI	0,0%	0,0%	11,3%	18,7%	26,0%	37,2%	48,9%
Diesel, Rigid 28 – 32 t	*Conventional*	55,2%	30,0%	22,4%	16,7%	12,8%	7,7%	4,4%
	Euro I	23,2%	13,3%	10,7%	8,4%	6,8%	4,0%	1,1%
	Euro II	21,6%	21,8%	17,6%	16,2%	15,4%	14,7%	14,5%
	Euro III	0,0%	24,8%	20,0%	16,3%	13,6%	9,1%	4,5%
	Euro IV	0,0%	10,2%	18,5%	24,1%	26,9%	29,2%	28,3%
	Euro V, VI	0,0%	0,0%	10,7%	18,3%	24,5%	35,4%	47,2%
Diesel, Rigid > 32 t	*Conventional*	55,2%	30,0%	22,4%	16,8%	12,9%	7,8%	4,5%
	Euro I	23,3%	13,3%	10,7%	8,5%	6,8%	4,1%	1,2%
	Euro II	21,6%	21,8%	17,6%	16,1%	15,4%	14,8%	14,8%
	Euro III	0,0%	24,8%	20,0%	16,4%	13,8%	9,4%	4,8%
	Euro IV	0,0%	10,1%	18,5%	23,9%	26,5%	28,0%	25,9%
	Euro V, VI	0,0%	0,0%	10,6%	18,3%	24,6%	35,9%	48,7%
Diesel, Articulated 14 – 20 t	*Conventional*	72,5%	49,7%	38,6%	31,1%	26,6%	19,3%	12,0%
	Euro I	15,8%	8,6%	7,1%	5,6%	4,7%	3,2%	1,6%
	Euro II	11,7%	11,8%	9,7%	8,9%	8,7%	8,6%	9,0%
	Euro III	0,0%	18,9%	15,9%	13,2%	11,5%	8,9%	6,4%
	Euro IV	0,0%	10,9%	18,9%	25,2%	27,2%	29,3%	29,0%
	Euro V, VI	0,0%	0,0%	9,9%	16,0%	21,3%	30,7%	42,0%
Diesel, Articulated 20 – 28 t	*Conventional*	72,5%	49,8%	38,6%	31,1%	26,6%	19,1%	11,6%
	Euro I	15,8%	8,6%	7,0%	5,6%	4,6%	3,0%	1,4%
	Euro II	11,7%	11,8%	9,7%	9,0%	8,8%	8,7%	9,1%
	Euro III	0,0%	18,9%	15,9%	13,2%	11,6%	9,0%	6,4%
	Euro IV	0,0%	10,9%	18,9%	25,2%	27,2%	29,4%	29,0%
	Euro V, VI	0,0%	0,0%	9,9%	16,0%	21,3%	30,9%	42,4%
Diesel, Articulated 28 – 34 t	*Conventional*	72,5%	49,8%	38,5%	31,1%	26,6%	19,2%	11,9%
	Euro I	15,8%	8,6%	7,1%	5,6%	4,7%	3,1%	1,5%
	Euro II	11,7%	11,8%	9,7%	8,9%	8,7%	8,7%	9,1%
	Euro III	0,0%	18,9%	15,9%	13,2%	11,6%	9,0%	6,5%
	Euro IV	0,0%	10,9%	18,8%	25,1%	27,0%	29,0%	28,4%
	Euro V, VI	0,0%	0,0%	9,9%	16,0%	21,3%	30,9%	42,6%
Diesel, Articulated 34 – 40 t	*Conventional*	72,5%	49,7%	38,6%	31,1%	26,6%	19,2%	11,9%
	Euro I	15,8%	8,6%	7,1%	5,6%	4,7%	3,1%	1,6%
	Euro II	11,7%	11,8%	9,7%	8,9%	8,7%	8,7%	9,1%
	Euro III	0,0%	18,9%	15,9%	13,2%	11,6%	9,0%	6,4%
	Euro IV	0,0%	10,9%	18,9%	25,1%	27,1%	29,2%	28,6%
	Euro V, VI	0,0%	0,0%	9,9%	16,0%	21,3%	30,8%	42,4%

Table 5 (continued)

Combinations of vehicle classification/technology		2000	2008	2013	2017	2020	2025	2030
Heavy Duty Trucks								
Diesel, Articulated 40 – 50 t	*Conventional*	72,6%	50,3%	39,0%	31,5%	26,9%	19,6%	12,2%
	Euro I	16,0%	8,4%	7,1%	5,5%	5,1%	3,0%	2,0%
	Euro II	11,3%	11,9%	9,9%	9,7%	9,7%	10,7%	10,9%
	Euro III	0,0%	18,2%	15,6%	13,3%	12,0%	9,5%	7,5%
	Euro IV	0,0%	11,2%	18,4%	23,0%	24,0%	22,6%	17,0%
	Euro V, VI	0,0%	0,0%	9,9%	17,0%	22,3%	34,5%	50,3%
Diesel, Articulated 50 – 60 t	*Conventional*	72,7%	50,0%	39,7%	34,4%	28,2%	20,0%	12,3%
	Euro I	15,9%	8,3%	6,9%	4,7%	5,6%	4,3%	1,5%
	Euro II	11,4%	11,7%	8,6%	3,1%	1,4%	0,0%	0,0%
	Euro III	0,0%	18,3%	17,2%	15,6%	14,1%	12,9%	9,2%
	Euro IV	0,0%	11,7%	19,0%	26,6%	28,2%	30,0%	30,8%
	Euro V, VI	0,0%	0,0%	8,6%	15,6%	22,5%	32,9%	46,2%
Urban Buses								
Diesel, Standard 15 – 18 t	*Conventional*	43,8%	3,7%	0,0%	0,0%	0,0%	0,0%	0,0%
	Euro I	17,2%	16,3%	8,2%	4,8%	3,1%	1,7%	0,9%
	Euro II	38,9%	28,6%	14,8%	8,7%	5,4%	2,7%	1,3%
	Euro III	0,0%	37,9%	31,1%	27,8%	23,9%	17,4%	10,2%
	Euro IV	0,0%	13,5%	29,0%	35,1%	39,1%	38,1%	32,2%
	Euro V, VI	0,0%	0,0%	16,8%	23,7%	28,5%	40,1%	55,4%
Coaches								
Diesel, Standard <= 18 t	*Conventional*	37,5%	11,6%	5,5%	2,4%	1,2%	0,3%	0,1%
	Euro I	55,1%	34,3%	18,4%	10,0%	5,9%	2,4%	1,0%
	Euro II	7,4%	15,0%	8,0%	3,1%	1,3%	0,3%	0,1%
	Euro III	0,0%	32,4%	17,3%	9,4%	5,5%	2,2%	0,9%
	Euro IV	0,0%	6,7%	26,7%	31,1%	30,3%	20,8%	4,2%
	Euro V, VI	0,0%	0,0%	24,0%	43,9%	55,9%	74,0%	93,8%
Motorcycles								
Gasoline, 4-stroke $\leq$ 250 cm^3	*Conventional*	85,3%	22,2%	9,5%	5,0%	3,1%	1,5%	0,6%
	EuroI	14,7%	15,5%	8,3%	5,3%	3,9%	2,4%	1,2%
	Euro II	0,0%	44,5%	49,5%	44,3%	35,9%	13,9%	2,4%
	Euro III, IV, V	0,0%	17,8%	32,8%	45,3%	57,1%	82,2%	95,7%
Gasoline, 4-stroke 250 – 750 cm^3	*Conventional*	85,2%	21,7%	9,6%	5,4%	3,6%	1,9%	0,9%
	EuroI	14,8%	15,3%	8,8%	6,3%	5,1%	3,9%	2,6%
	Euro II	0,0%	45,0%	49,7%	45,0%	37,2%	15,6%	2,9%
	Euro III, IV, V	0,0%	18,0%	31,8%	43,3%	54,1%	78,6%	93,7%
Gasoline, 4-stroke >= 750 cm^3	*Conventional*	88,9%	32,3%	23,0%	17,9%	14,1%	8,8%	4,1%
	EuroI	11,1%	11,4%	8,2%	6,5%	5,4%	3,8%	2,1%
	Euro II	0,0%	35,3%	39,7%	39,0%	36,2%	20,1%	4,1%
	Euro III, IV, V	0,0%	21,0%	29,2%	36,5%	44,3%	67,3%	89,7%
Mopeds								
Gasoline, 2–stroke < 50 cm^3	*Conventional*	52,8%	36,4%	18,9%	9,6%	5,5%	2,1%	0,8%
	EuroI	47,2%	53,4%	49,2%	34,1%	25,0%	14,5%	8,1%
	Euro II	0,0%	10,2%	21,5%	26,5%	28,3%	28,7%	26,3%
	Euro III, IV, V	0,0%	0,0%	10,3%	29,8%	41,1%	54,8%	64,8%

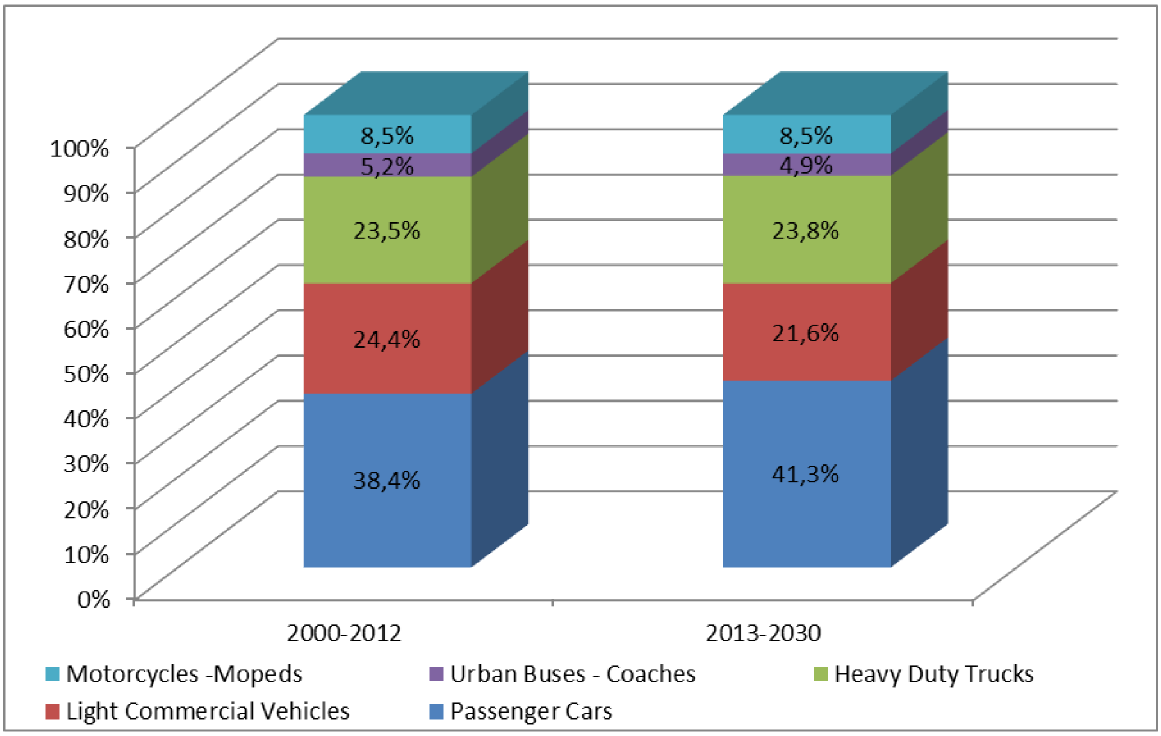
Table 6: Estimated greenhouse gas emissions (in Mt of CO_2 equivalent) for the periods 2000-2012 and 2013-2030

	Vehicle Classifications	2000 – 2012		2013 – 2030		% Change
		Quantity	%	Quantity	%	
Passenger Cars	*Gasoline 0,8 - 1,4 l*	53,620	55,90%	39,885	42,40%	-25,6%
	Gasoline 1,4 - 2 l	34,472	35,94%	26,359	28,02%	-23,5%
	Gasoline > 2 l	2,547	2,66%	1,984	2,11%	-22,1%
	Diesel < 2 l	2,622	2,73%	16,628	17,68%	+534,2%
	Diesel > 2 l	1,377	1,44%	4,682	4,98%	+240,0%
	LPG	1,257	1,31%	4,495	4,78%	+257,5%
	Gasoline Hybrids	0,019	0,02%	0,036	0,04%	+88,6%
	Total	***95,914***	***100,0%***	***94,069***	***100,0%***	***-1,9%***
Light Commercial Vehicles	*Gasoline < 3,5 t*	42,073	69,07%	28,855	58,67%	-31,4%
	Diesel < 3,5 t	18,838	30,93%	20,329	41,33%	7,9%
	Total	***60,912***	***100,0%***	***49,184***	***100,0%***	***-19,3%***
Heavy Duty Trucks	*Gasoline > 3,5 t*	2,247	3,83%	1,329	2,45%	-40,9%
	Diesel Rigid <= 7,5 t	12,143	20,69%	11,238	20,71%	-7,5%
	Diesel Rigid 7,5 − 12 t	8,220	14,01%	7,715	14,22%	-6,1%
	Diesel Rigid 12 − 14 t	2,300	3,92%	2,160	3,98%	-6,1%
	Diesel Rigid 14 − 20 t	7,878	13,42%	7,365	13,57%	-6,5%
	Diesel Rigid 20 − 26 t	7,019	11,96%	6,556	12,08%	-6,6%
	Diesel Rigid 26 − 28 t	0,018	0,03%	0,017	0,03%	-9,0%
	Diesel Rigid 28 − 32 t	0,657	1,12%	0,619	1,14%	-5,8%
	Diesel Rigid > 32 t	4,318	7,36%	4,036	7,44%	-6,5%
	Diesel Articulated 14 − 20 t	1,095	1,87%	1,045	1,93%	-4,6%
	Diesel Articulated 20 − 28 t	0,787	1,34%	0,746	1,38%	-5,2%
	Diesel Articulated 28 − 34 t	0,680	1,16%	0,646	1,19%	-5,0%
	Diesel Articulated 34 − 40 t	11,245	19,16%	10,713	19,75%	-4,7%
	Diesel Articulated 40 − 50 t	0,053	0,09%	0,048	0,09%	-7,8%
	Diesel Articulated 50 − 60 t	0,022	0,04%	0,020	0,04%	-8,2%
	Total	***58,683***	***100,0%***	***54,252***	***100,0%***	***-7,6%***
Urban Buses, Standard Coaches	*Diesel* Buses Standard 15-18t	1,045	8,11%	0,770	6,91%	-26,3%
	Diesel Coaches <= 18t	11,839	91,89%	10,370	93,09%	-12,4%
	Total	***12,884***	***100,0%***	***11,140***	***100,0%***	-13,5%
4-stroke	Gasoline < 250 cm^3	12,325	58,16%	11,699	60,39%	-5,1%
Motorcycles,	Gasoline 250 - 750 cm^3	6,271	29,59%	5,660	29,22%	-9,7%
2-stroke	Gasoline > 750 cm^3	1,669	7,88%	1,362	7,03%	-18,4%
Mopeds	Gasoline <50 cm^3	0,925	4,37%	0,650	3,36%	-29,7%
	Total	***21,191***	***100,0%***	***19,371***	***100,0%***	-8,6%
GENERAL TOTAL		***249,583***		***228,016***		***-8,6%***

On the contrary, for the diesel, LPG, and gasoline Hybrid PCs, CO_2 emissions are higher in the second period. Especially, for the diesel PCs less than 2 l, CO_2 emissions are five times more in the second period compared to the first period. This implies that the introduction of new technologies in diesel PCs leads to large increases in emissions due to the trade-off between less fuel consumption which is achieved by new technologies and the longer average distance traveled in combination with lower fuel price per liter. Eventually, the aforementioned large increases of emissions is the main cause for the small percentage decrease (-1,9%) of CO_2 emissions for all the PCs classifications between the two periods.

Similar comments with those for PCs can be made for the Light Commercial Vehicles (LCVs). Between the two periods, it is expected that gasoline LCVs will emit less CO_2 in the second period (reduction by 31,4%), while diesel LCVs will emit more (increase by 7,9%). Nonetheless, in both periods gasoline LCVs have the largest share of CO_2 emitted totally by LCVs. This has as result the reduction of CO_2 emissions between the two periods by 19,3% for LCVs.

Figure 1: Shares of CO_2 emissions for the general vehicle categories



The penetration of Euro IV,V, VI standards into the Heavy Duty Trucks (HDTs) fleet leads to reductions of CO_2 emissions for all the classifications. The highest reduction is observed for the gasoline HDTs (-40,9%) while for the remaining classifications the reduction ranges from 4,6% to 9%. In both periods, the highest share in CO_2 emitted totally by HDTs is possessed by the Rigid HDTs with weight ≤ 7,5 t (20,69% for 2000-2012 and 20,71% for 2013-2030). The second most important source of CO_2 emissions is the Articulated HDTs with weight 34−40t (with share 19,16% for the first period and 19,75% for the second period) followed by the Rigid HDTs with weight 7,5−12t (with shares 14,01% and 14,22% respectively) and the Rigid HDTs 14−20t (13,42% and 13,57%). For the HDTs as a whole, CO_2 emissions are expected to be reduced between the two periods by 7,6%.

Regarding motorcycles and mopeds, all the classifications display reductions in CO_2 emissions between the two periods. The highest reductions are observed for the mopeds and the motorcycles with engine capacity greater than 750 cm^3 (-29,7% and -18,4% respectively). On the contrary, the motorcycles with engine capacities <250cm^3 and 250−750cm^3 are the most important sources of CO_2 emissions. For the first classification the shares are 58,16% for 2000-2012 and 60,39% for 2013-2030, while for the second classification the corresponding shares are 29,59% and 29,22%. A whole vehicle category, motorcycles-mopeds will emit CO_2 in the second period reduced by 8,6% compared to the first period.

Finally, for urban buses and coaches, CO_2 emissions were calculated only for the classifications Standard Buses with weight 15-18t and Coaches with weight less than 18t. For the remaining classifications, computations were not possible as data for the average fuel consumptions are not available. Among the two classifications for which CO_2 emissions have been calculated, coaches are the most important source of pollution with share more than 90% for both periods. Also taking these two classifications as a vehicle category, CO_2 emissions are expected to be reduced between the two periods by 13,5%.

5. Abatement cost curves for the road transport in Greece

In this section, we estimate the total cost related to each vehicle technology scenario incorporated into the corresponding vehicle classification of Table 1, first for the period 2000-2012 and then for the period 2013-2030. In period 2000-2012 the share of vehicles with at least Euro 5 standards (or Euro V for trucks) was relatively small in the fleet in circulation at the end of each year. On the other hand, for the period 2013-2030 the penetration rate of these very recent Euro standards is very high as this was shown in Table 5. Therefore the difference of the total cost between periods 2013-2030 and 2000-2012 is considered as abatement cost, since, from Section 4, for the majority of vehicle classifications we observed decreases in greenhouse gas emissions expressed in CO_2 equivalent.

For scenario i incorporated in the corresponding i vehicle classification, the total cost at 2013 prices is given by

$$TC_i = \sum_t \sum_k S_{i,k,t} \times P_k + \sum_t \sum_k N_{i,k,t} \times (L_k + A_k + M_k) + \sum_t \sum_s B_s \times D_{i,s,t} \,. \tag{8}$$

where:

$S_{i,k,t}$ stands for vehicle sales of the k combination of vehicle classification/technology for year t,

P_k is the average price of vehicle (including VAT and registration tax) which belongs to the k combination of vehicle classification/technology at 2013 prices,

$N_{i,k,t}$ is the number of vehicles in circulation belonging to the k combination of vehicle classification/technology at the end of year t,

L_k is the annual average ownership tax for vehicles belonging to the k combination of vehicle classification/technology at 2013 prices,

A_k is the annual average insurance cost for vehicles belonging to the k combination of vehicle classification/technology at 2013 prices,

M_k is the annual average service cost for vehicles belonging to the k combination of vehicle classification/technology at 2013 prices,

B_s is the cost of fuel at 2013 prices (in kg per km) of the s fuel type (Gasoline, Diesel, LPG).

$D_{i,s,t}$ is the average total distance driven in year t by vehicles using fuel type s, and

t takes on values either from 2000 to 2012 or from 2013 to 2030.

For the period 2000-2013, we took as vehicle sales for each year the numbers of new registrations as the latter ones are given by EL.STAT. For mopeds, the number of new registrations was taken from EMISSIA SA. For the period 2014-2030 and for each vehicle category, we assume that the percentage of erased/withdrawn vehicles in the total number of vehicles in circulation at the end of each year will be equal to the average percentage calculated from the data of Table A2. Then for each year between 2014 and 2030 and for each vehicle category, first we calculated the number of erased/withdrawn vehicles using the corresponding average percentage of erased/withdrawn vehicles. Then we estimated the number of sales by taking the sum of the number of erased/withdrawn vehicles and the difference in the number of vehicles in circulation between years $t+1$ and t. For each vehicle category, the sales were distributed across the different combinations of vehicle classifications/technology proportionally according to the number of vehicles in each combination. Further details for the construction of (8) can be found in Halkos et al. (2014b).

For the determination of P_k, L_k, A_k and M_k, we used the data of Emissia SA referring to 2009 prices. For the adjustment of the various costs at 2013 prices, we used from

EL.STAT[6] appropriate price indices with base year 2009. For all the vehicle classifications, the values of P_k, L_k, A_k and M_k are displayed in Table 7.

Table 7: Cost elements (in €) per vehicle at 2013 prices

Technology Scenario	Average Price (including VAT and registration tax) ($P_κ$)	Average ownership tax ($L_κ$)	Average Insurance cost ($A_κ$)	Average Service cost ($M_κ$)
Gasoline Passenger Cars, 0,8 - 1,4 l	12.152,98	209,87	509,52	358,58
Gasoline Passenger Cars, 1,4 - 2 l	23.229,97	439,55	724,63	505,49
Gasoline Passenger Cars, > 2 l	39.884,74	1.129,22	1.077,72	668,42
Diesel Passenger Cars, < 1,4	13.825,86	362,92	560,48	369,34
Diesel Passenger Cars, 1,4 - 2 l	25.032,60	546,02	797,09	520,66
Diesel Passenger Cars, > 2 l	42.015,69	1.129,22	1.185,49	688,47
LPG Passenger cars	26.867,61	499,17	828,15	526,81
Gasoline Hybrid cars	26.867,61	622,65	828,15	526,81
Light Commercial Vehicles Gasoline <3,5t	20.779,14	105,63	1.028,33	1.012,05
Light Commercial Vehicles Diesel <3,5t	21.569,63	105,63	1.049,32	1.032,70
Heavy Duty Trucks, Gasoline >3,5 t Conventional	27.499,24	295,29	1.248,95	1.921,70
Heavy Duty Trucks: Rigid <= 7,5 t	27.499,24	295,29	1.248,95	1.921,70
Heavy Duty Trucks: Rigid 7,5 - 12 t	35.459,26	590,59	1.421,55	2.133,09
Heavy Duty Trucks: Rigid 12 - 14 t	38.444,27	590,59	1.479,08	2.367,73
Heavy Duty Trucks: Rigid 14 - 20 t	50.384,31	590,59	1.824,29	2.628,18
Heavy Duty Trucks: Rigid 20 - 26 t	62.324,35	929,10	2.169,49	2.917,28
Heavy Duty Trucks: Rigid 26 - 28 t	70.284,38	929,10	2.399,63	3.238,18
Heavy Duty Trucks: Rigid 28 - 32 t	76.254,40	929,10	2.572,23	3.594,38
Heavy Duty Trucks: Rigid > 32 t	80.234,42	929,10	2.802,37	3.989,76
Heavy Duty Trucks: Articulated 14 - 20 t	32.395,34	885,88	1.824,29	2.628,18
Heavy Duty Trucks: Articulated 20 - 28 t	40.835,70	1.224,39	2.227,02	3.022,40
Heavy Duty Trucks: Articulated 28 - 34 t	51.687,59	1.604,91	2.629,76	3.475,76
Heavy Duty Trucks: Articulated 34 - 40 t	56.510,65	1.604,91	2.974,97	3.823,34
Heavy Duty Trucks: Articulated 40 - 50 t	66.156,78	1.774,16	3.435,24	4.205,67
Heavy Duty Trucks: Articulated 50 - 60 t	78.214,43	1.774,16	3.783,57	4.626,24
Urban Buses Standard 15 - 18 t	183.037,67	506,49	3.288,53	3.899,10
Coaches Standard <= 18 t	198.571,98	506,49	3.441,48	4.289,01
Motorcycles 4-stroke: < 250 cm^3	3.673,01	55,22	231,67	230,72
Motorcycles 4-stroke: 250 - 750 cm^3	3.673,01	55,22	231,67	230,72
Motorcycles 4-stroke: > 750 cm^3	3.673,01	55,22	231,67	230,72
Mopeds 2-stroke <50 cm^3	1.526,03	21.37	89.76	75.3

Taking the selling price of fuel from the Ministry of Development and Competitiveness for the period 04.01.2013 to 27.12.2013, averages were obtained over this period, which are displayed in Table 8 in euro per liter. But for the conversion of the fuel price from liters to kilograms the specific weight for each fuel type was needed. The specific

[6] http://www.statistics.gr/portal/page/portal/ESYE/PAGE-themes?p_param=A0515&r_param=DKT87&y_param=2013_12&mytabs=0

weight was set equal to 0,725 for gasoline, 0.845 for diesel, and 0.545 for LPG. Multiplying these specific weights by the fuel price per liter we transformed the fuel prices to € per kg, and these latter fuel prices were taken as values of B_s, which are also presented in Table 8.

Table 8: Average fuel price (in €) for 2013

	Unleaded 95	DIESEL	LPG
€/lt	1,69	1,39	0,89
€/kg	1,2252	1,1746	0,4851

Substituting the values of Tables 7 and 8 into equation (8), we obtain the total costs related to each vehicle technology scenario first for the period 2000-2012, and then for the period 2013-2030. The results are presented in Table 9 and in Figure 2. At first, it is observed that the introduction of the most recent technologies (e.g. Euro 5, 6 etc) to the Greek vehicle fleet will have as a result the cost to be increased between the periods 2000-2012 and 2013-2030 from 299,817 to 434,434 billion € (+44,9%). For the two periods under consideration, the Passenger Cars are responsible for 56,0% of total cost in the first period and for 59,2% of total cost in the second period. The second highest contribution to the total cost is attributed to the Light Commercial Vehicles (with share 19,1% in 2000-2012 and 17,7% in 2013-2030), followed by the Heavy Duty Trucks (with 15,3% in the first period and 13,5% in the second period), and the Motorcycles-Mopeds (with 6,8% in the first period and 7,3% in the second period).

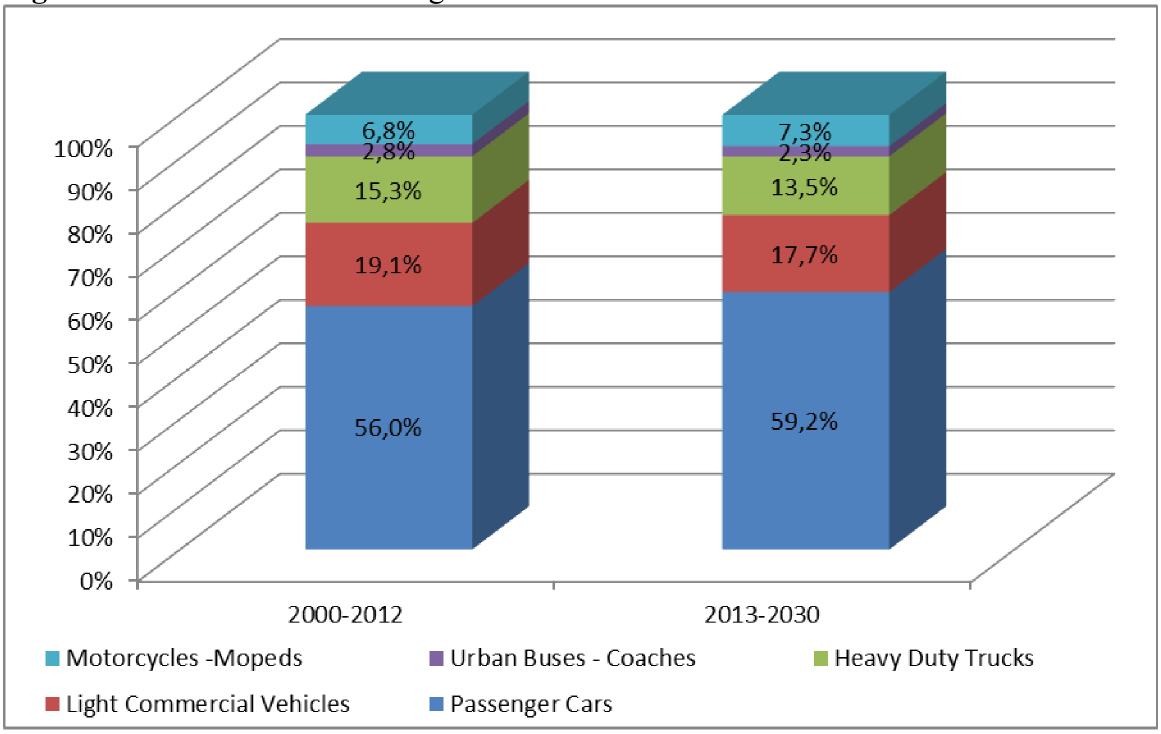
For the Passenger Cars (PCs), the highest contribution to their total cost is attributed to the gasoline PCs with engine capacities 0,8-1,4l (with share 50,45% for the first period 2000-2012 and 38,89% for the second period 2013-2030) and 1,4-2l (with 40,40% for the first period and 30,72% for the second period 2013-2030). It is also expected that the diesel PCs with engine capacity less than 2l will have the third highest contribution to the total cost for the period 2013-2030 with share 21,47%, compared to 3,24% of the first period 2000-2012. Between the two periods under consideration, we face cost increases in all the classifications of gasoline PCs ranging from +0,1% to +18,1%. The same trends also hold for the diesel, LPG, and gasoline Hybrid PCs but with much larger percentage increases between the two periods. Especially, for the diesel PCs less than 2l, cost increases in the second period by more than nine times compared to the first period. These large increases for the diesel and LPG PCs is the main cause for 53,3% increase in the total cost for all the PCs classifications between the two periods.

Table 9: Estimated total cost (in billion €) of vehicle classifications

Vehicle Categories		2000 – 2012		2013 – 2030		% Change
		Amount	%	Amount	%	
Passenger Cars	*Gasoline 0,8 - 1,4 l*	84,657	50,45%	100,022	38,89%	+18,1%
	Gasoline 1,4 - 2 l	67,802	40,40%	79,003	30,72%	+16,5%
	Gasoline > 2 l	6,082	3,62%	6,088	2,37%	+0,1%
	Diesel < 2 l	5,439	3,24%	55,216	21,47%	+915,1%
	Diesel > 2 l	3,249	1,94%	14,935	5,81%	+359,7%
	LPG	0,430	0,26%	1,682	0,65%	+291,1%
	Gasoline Hybrids	0,147	0,09%	0,243	0,09%	+65,8%
	Total	***167,806***	***100,0%***	***257,189***	***100,0%***	***+53,3%***
Light Commercial Vehicles	*Gasoline < 3,5 t*	38,702	67,55%	48,434	63,05%	+25,1%
	Diesel < 3,5 t	18,592	32,45%	28,384	36,95%	+52,7%
	Total	***57,294***	***100,0%***	***76,818***	***100,0%***	***+34,1%***
Heavy Duty Trucks	*Gasoline > 3,5 t*	1,343	2,92%	1,261	2,14%	-6,1%
	Diesel Rigid<= 7,5 t	10,492	22,81%	13,768	23,39%	+31,2%
	Diesel Rigid 7,5 − 12 t	6,337	13,78%	8,088	13,74%	+27,6%
	Diesel Rigid 12 − 14 t	1,841	4,00%	2,373	4,03%	+28,9%
	Diesel Rigid 14 − 20 t	6,136	13,34%	7,779	13,22%	+26,8%
	Diesel Rigid 20 − 26 t	5,752	12,51%	7,378	12,54%	+28,3%
	Diesel Rigid 26 − 28 t	0,016	0,03%	0,020	0,03%	+28,3%
	Diesel Rigid 28 −32 t	0,595	1,29%	0,793	1,35%	+33,1%
	Diesel Rigid> 32 t	3,691	8,03%	4,750	8,07%	+28,7%
	Diesel Articulated 14 − 20 t	0,708	1,54%	0,898	1,53%	+26,9%
	Diesel Articulated 20 − 28 t	0,534	1,16%	0,682	1,16%	+27,7%
	Diesel Articulated 28 − 34 t	0,483	1,05%	0,624	1,06%	+29,2%
	Diesel Articulated 34 − 40 t	8,006	17,41%	10,370	17,62%	+29,5%
	Diesel Articulated 40 − 50 t	0,040	0,09%	0,049	0,08%	+23,4%
	Diesel Articulated 50 − 60 t	0,017	0,04%	0,021	0,04%	+23,6%
	Total	***45,990***	***100,0%***	***58,853***	***100,0%***	***+28,0%***
Urban Buses, Standard Coaches	*Diesel* Buses Standard 15-18t	0,336	3,98%	0,643	6,39%	+91,3%
	Diesel Coaches <=18t	8,103	96,02%	9,427	93,61%	+16,3%
	Total	***8,439***	***100,0%***	***10,070***	***100,0%***	***+19,3%***
4-stroke Motorcycles, 2-stroke Mopeds	Gasoline< 250 cm^3	11,853	58,42%	18,862	59,87%	+59,1%
	Gasoline 250 - 750 cm^3	5,843	28,80%	8,966	28,46%	+53,4%
	Gasoline> 750 cm^3	1,276	6,29%	1,664	5,28%	+30,4%
	Gasoline <50 cm^3	1,316	6,49%	2,011	6,38%	+52,8%
	Total	***20,289***	***100,0%***	***31,504***	***100,0%***	***+55,3%***
GENERAL TOTAL		***299,817***		***434,434***		***+44,9%***

Similar comments with those for PCs can be made for the Light Commercial Vehicles (LCVs). Between the two periods, it is expected that LCVs will cost more in the second period (increase by 25,1% for gasoline and 52,7% for diesel LCVs). In both periods diesel LCVs have the largest share in their total cost, and this has as a result the percentage increase of total cost between the two periods to reach 34,1%.

Figure 2: Shares of vehicles categories in the total cost



The penetration of Euro IV,V, VI standards into the Heavy Duty Trucks (HDTs) fleet leads to cost increases for all the classifications except that one of the gasoline HDTs. The percentage increases in the cost range between +23,4% and 33,1%. This has as a result the total cost for the HDTs to increase between the two periods by 28%. The highest contribution to the HDTs total cost is attributed to those HDTs with weight ≤ 7,5t (22,81% for 2000-2012 and 23,39% for 2013-2030). The second highest contribution is attributed to the Articulated HDTs with weight 34−40t (with share 17,41% for the first period and 17,62% for the second period) followed by the Rigid HDTs with weight 7,5−12t (with shares 13,78% and 13,74% respectively) and the Rigid HDTs 14−20t (13,34% and 13,22%).

Regarding motorcycles and mopeds, all the classifications display increases in the costs between the two periods. The highest percentage increase is observed for the motorcycles with engine capacity less than 250 cm^3 (59,1%). The highest contribution to the total cost of motorcycles and mopeds is attributed to those motorcycles with engine capacities <250 cm^3 and 250−750 cm^3. For the first classification the shares are 58,42% for 2000-2012 and 59,87% for 2013-2030, while for the second classification the corresponding shares are 28,80% and 28,46%. As a whole vehicle category, motorcycles-mopeds will cost more in the second period. Particularly, for 2013-2030 the total cost increases by 55,3% compared to the period 2000-2012.

Finally, for urban buses and coaches, costs were calculated only for the classifications Standard Buses with weight 15-18t and Coaches with weight less than 18t. Among these two classifications, coaches contribute the most to the total cost with share exceeding 90% for both periods. Also taking these two classifications as a vehicle category, total cost is expected to grow between the two periods by 19,3%.

Combining the results of Tables 6 and 9, we present in Table 10 the marginal abatement costs (MAC) at 2013 prices for all the vehicle classifications for which between the periods 2000-2012 and 2013-2030 reductions in the CO_2 emissions and increase or decrease in the corresponding costs have been observed. We excluded as uneconomic the cases of Diesel, LPG and Hybrid Passenger Cars, as well as the Diesel Light Commercial Vehicles, for which we found increases in both emissions and costs. From Table 10 we realize that only 4 out of the 26 scenarios have MAC below 1000 €, and also 4 out of the 26 scenarios MAC between 1000 and 2000 €. All the remaining scenarios are considered as less effective since their MAC exceeds 2000 €. Furthermore, Table 11 presents the marginal abatement costs for the general vehicle categories. Observe that the high penetration of the most recent technology standards in the fleet of rigid and articulated heavy duty trucks as well as in the fleet of motorcycles and mopeds (e.g. Euro V, VI for trucks and Euro III, IV for motorcycles and Mopeds) constitutes a less effective policy since between 2000-2012 and 2013-2030 their marginal abatement costs exceed 2500 € per ton CO_2 eq.

Table 10: Marginal abatement cost (MAC) for vehicle classifications

Vehicle Technology Scenarios	Between periods 2000-2012 and 2013-2030		
	Greenhouse gas emissions reduction in CO2 eq. (in tons)	Cost increase (in €)	MAC in € per ton CO2 eq.
Heavy Duty Trucks, Gasoline >3,5 Conventional	918.136,086	-81.945.750,08	-89,25
Gasoline Passenger Cars, > 2 l	562.719,584	5.903.027,78	10,49
Light Commercial Vehicles Gasoline <3,5t	13.218.817,249	9.732.953.189,86	736,30
Coaches Standard <= 18t	1.468.728,881	1.324.560.758,51	901,84
Urban Buses, Standrad 15 - 18 t	274.587,382	307.019.582,20	1.118,11
Gasoline Passenger Cars, 0,8 - 1,4 l	13.735.695,590	15.364.813.592,79	1.118,60
Motorcycles 4-stroke: > 750 cm^3	307.100,217	388.225.605,05	1.264,17
Gasoline Passenger Cars, 1,4 - 2 l	8.113.300,208	11.200.695.584,14	1.380,54
Heavy Duty Trucks: Articulated 40 - 50 t	4.123,261	9.280.866,64	2.250,86
Heavy Duty Trucks: Articulated 50 - 60 t	1.776,583	4.085.463,72	2.299,62
Mopeds 2-stroke <50 cm^3	275.070,218	695.000.277,31	2.526,63
Heavy Duty Trucks: Rigid 26 - 28 t	1.630,499	4.411.352,09	2.705,52
Heavy Duty Trucks: Rigid 14 - 20 t	513.258,405	1.643.271.008,33	3.201,64
Heavy Duty Trucks: Rigid 7,5 - 12 t	505.538,895	1.751.442.432,94	3.464,51
Heavy Duty Trucks: Rigid 20 - 26 t	463.439,818	1.625.862.182,96	3.508,25
Heavy Duty Trucks: Articulated 20 - 28 t	41.073,822	147.759.748,87	3.597,42
Heavy Duty Trucks: Rigid <= 7,5 t	905.400,557	3.275.368.149,68	3.617,59
Heavy Duty Trucks: Rigid > 32 t	282.657,403	1.059.412.643,44	3.748,04
Heavy Duty Trucks: Articulated 14 - 20 t	50.417,671	190.042.806,97	3.769,37
Heavy Duty Trucks: Rigid 12 - 14 t	139.843,178	531.975.322,51	3.804,08
Heavy Duty Trucks: Articulated 28 - 34 t	33.965,270	140.995.501,08	4.151,17
Heavy Duty Trucks: Articulated 34 - 40 t	531.775,086	2.363.848.118,52	4.445,20
Motorcycles 4-stroke: 250 - 750 cm^3	611.339,146	3.122.744.966,98	5.108,04
Heavy Duty Trucks: Rigid 28 - 32 t	38.091,003	197.249.507,67	5.178,38
Motorcycles 4-stroke: < 250 cm^3	626.156,496	7.008.977.889,28	11.193,65

Following the above analysis, we are closing this report by presenting the MAC curves for the vehicle technology scenarios of table 11 and for the general vehicle categories of Table 10. The two MAC curves are illustrated in Figures 3 and 4 respectively.

Table 11: Marginal abatement costs for the general categories of vehicles

Vehicle Technology Scenarios	Between periods 2000-2012 and 2013-2030		
	Greenhouse gas emissions reduction in CO2 eq. (in tons)	Cost increase (in €)	MAC in € per ton CO2 eq.
Heavy Duty Trucks, Gasoline >3,5 Conventional	918.136,086	-81.945.750,08	-89,25
Light Commercial Vehicles Gasoline <3,5t	13.218.817,249	9.732.953.189,86	736,30
Coaches Standard <= 18t	1.468.728,881	1.324.560.758,51	901,84
Urban Buses, Standrad 15 - 18 t	274.587,382	307.019.582,20	1.118,11
Gasoline Passenger cars	22.411.715,381	26.571.412.204,70	1.185,60
Mopeds 2-stroke <50 cm³	275.070,218	695.000.277,31	2.526,63
Heavy Duty Trucks, Rigid	2.849.859,758	10.088.992.599,63	3.540,17
Heavy Duty Trucks, Articulated	663.131,694	2.856.012.505,80	4.306,86
Motorcycles 4-stroke	1.544.595,860	10.519.948.461,31	6.810,81

Figure 3: MAC curve at 2013 prices for general vehicle categories

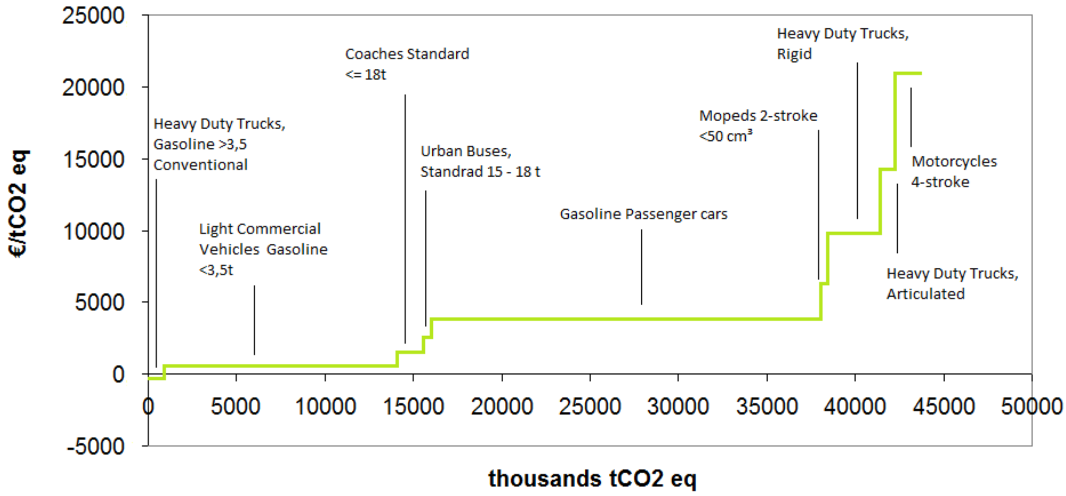
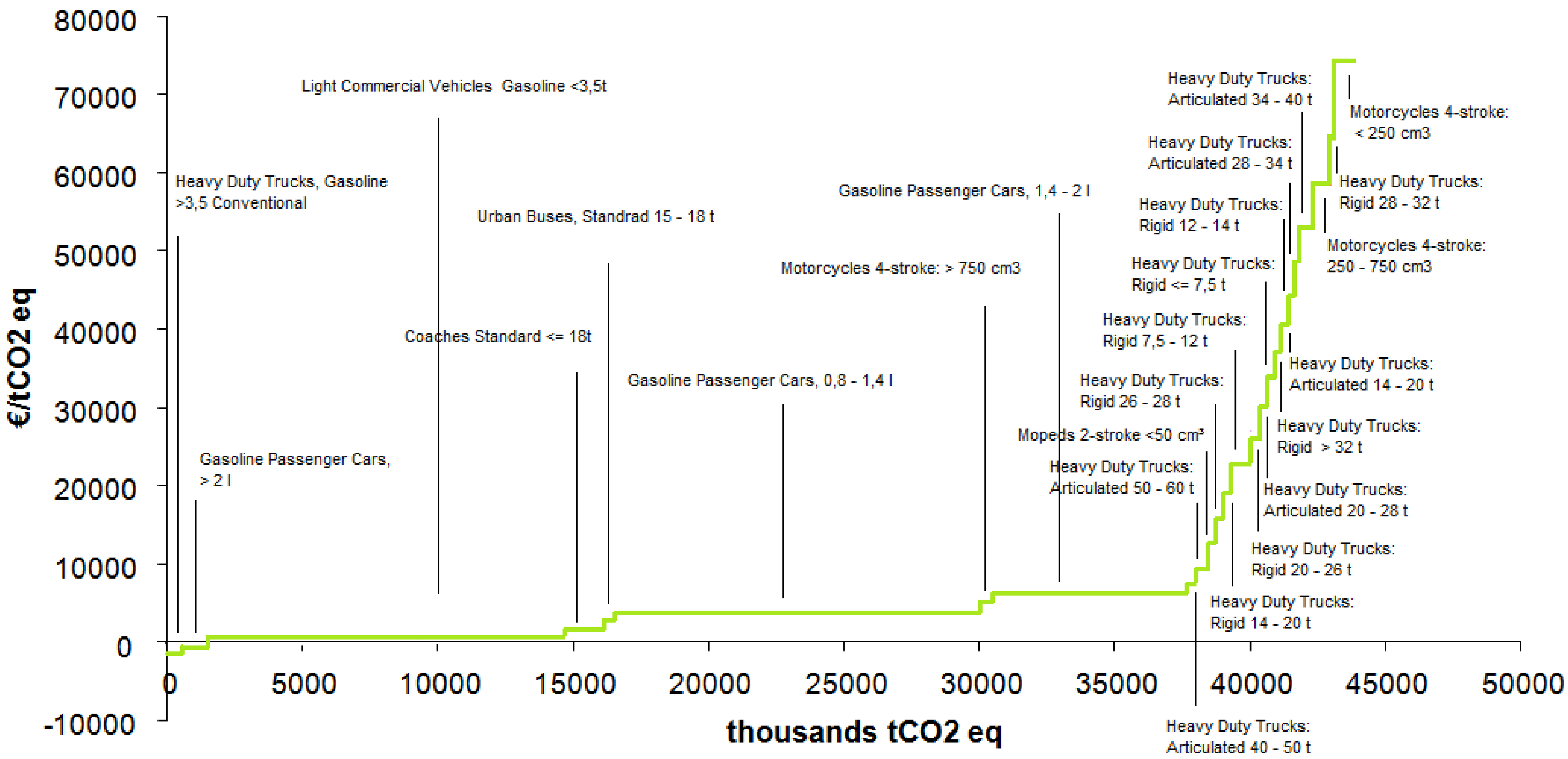


Figure 4: MAC curve at 2013 prices for various vehicle classifications with high penetration rates of the most recent Euro standards for the period 2013-2030



Appendix of Tables

Table A1: Time series for the number of Vehicles in circulation in Greece at the end of each year for the period 1985-2013

	Passenger Cars		Trucks		Buses		Motorcycles	
Year	**Number**	**Rate of Change**	**Number**	**Rate of Change**	**Number**	**Rate of Change**	**Number**	**Rate of Change**
1985	1.259.335		595.761		19.234		162.295	
1986	1.355.142	7,61%	622.037	4,41%	19.482	1,29%	173.694	7,02%
1987	1.428.546	5,42%	650.950	4,65%	19.745	1,35%	183.253	5,50%
1988	1.503.921	5,28%	683.700	5,03%	20.074	1,67%	197.995	8,04%
1989	1.605.181	6,73%	724.203	5,92%	20.653	2,88%	219.547	10,89%
1990	1.735.523	8,12%	766.429	5,83%	21.430	3,76%	256.594	16,87%
1991	1.777.484	2,42%	792.770	3,44%	22.080	3,03%	295.675	15,23%
1992	1.829.100	2,90%	797.788	0,63%	22.674	2,69%	339.774	14,91%
1993	1.958.544	7,08%	825.697	3,50%	23.206	2,35%	387.877	14,16%
1994	2.074.081	5,90%	849.033	2,83%	23.540	1,44%	428.953	10,59%
1995	2.204.761	6,30%	883.823	4,10%	24.600	4,50%	475.668	10,89%
1996	2.339.421	6,11%	914.827	3,51%	25.096	2,02%	517.890	8,88%
1997	2.500.099	6,87%	951.785	4,04%	25.622	2,10%	570.965	10,25%
1998	2.675.676	7,02%	987.357	3,74%	26.320	2,72%	633.765	11,00%
1999	2.928.881	9,46%	1.023.987	3,71%	26.769	1,71%	710.775	12,15%
2000	3.195.065	9,09%	1.057.422	3,27%	27.037	1,00%	781.361	9,93%
2001	3.423.704	7,16%	1.085.811	2,68%	27.115	0,29%	853.366	9,22%
2002	3.646.069	6,49%	1.109.137	2,15%	27.247	0,49%	910.555	6,70%
2003	3.839.549	5,31%	1.131.027	1,97%	27.139	-0,40%	969.895	6,52%
2004	4.073.511	6,09%	1.159.137	2,49%	26.780	-1,32%	1.042.605	7,50%
2005	4.303.129	5,64%	1.186.483	2,36%	26.829	0,18%	1.124.172	7,82%
2006	4.543.016	5,57%	1.219.889	2,82%	26.938	0,41%	1.205.816	7,26%
2007	4.798.530	5,62%	1.255.945	2,96%	27.102	0,61%	1.298.688	7,70%
2008	5.023.944	4,70%	1.289.525	2,67%	27.186	0,31%	1.388.607	6,92%
2009	5.131.960	2,15%	1.302.430	1,00%	27.324	0,51%	1.448.851	4,34%
2010	5.216.873	1,65%	1.318.768	1,25%	27.311	-0,05%	1.499.133	3,47%
2011	5.203.591	-0,25%	1.321.296	0,19%	27.121	-0,70%	1.534.902	2,39%
2012	5.167.557	-0,69%	1.318.918	-0,18%	26.962	-0,59%	1.556.435	1,40%
2013	5.124.208	-0,84%	1.315.836	-0,23%	26.783	-0,66%	1.568.596	0,78%

Source: EL.STAT

Table A2: Time series for the number of vehicles (new plus used) which were first released in Greece from 2000 until 2013

YEAR	PASSENGER CARS			TRUCKS		
	New Registrations	Withdrawn-erased		New Registrations	Withdrawn-erased	
		Number	*% in the total number of vehicles in circulation at the end of each year*		*Number*	*% in the total number of vehicles in circulation at the end of each year*
2000	302.620	73.981	2,32%	46.421	18.032	1,71%
2001	289.943	67.578	1,97%	47.047	23.721	2,18%
2002	277.567	84.087	2,31%	46.466	24.576	2,22%
2003	272.515	38.553	1,00%	48.925	20.815	1,84%
2004	317.508	87.890	2,16%	54.201	26.855	2,32%
2005	302.613	62.726	1,46%	51.991	18.585	1,57%
2006	304.700	49.186	1,08%	53.422	17.366	1,42%
2007	317.879	92.465	1,93%	53.828	20.248	1,61%
2008	295.853	187.837	3,74%	50.391	37.486	2,91%
2009	244.539	159.626	3,11%	37.338	21.000	1,61%
2010	153.847	167.129	3,20%	29.213	26.685	2,02%
2011	107.737	143.771	2,76%	18.270	20.648	1,56%
2012	64.301	107.650	2,08%	12.917	15.999	1,21%
2013	64.932			13.312		

Source: EL.STAT for New Registrations

YEAR	BUSES			MOTORCYCLES		
	New Registrations	Withdrawn-erased		New Registrations	Withdrawn-erased	
		Number	*% in the total number of vehicles in circulation at the end of each year*		*Number*	*% in the total number of vehicles in circulation at the end of each year*
2000	1.480	1.402	5,19%	72.800	795	0,10%
2001	1.909	1.777	6,55%	76.155	18.966	2,22%
2002	1.780	1.888	6,93%	61.666	2.326	0,26%
2003	2.386	2.745	10,11%	65.599	-7.111	-0,73%
2004	2.347	2.298	8,58%	79.635	-1.932	-0,19%
2005	1.255	1.146	4,27%	90.126	8.482	0,75%
2006	1.026	862	3,20%	92.183	-689	-0,06%
2007	1.185	1.101	4,06%	103.879	13.960	1,07%
2008	1.110	972	3,58%	102.774	42.530	3,06%
2009	1.536	1.549	5,67%	73.115	22.833	1,58%
2010	817	1.007	3,69%	61.763	25.994	1,73%
2011	365	524	1,93%	47.754	26.221	1,71%
2012	457	636	2,36%	33.687	21.526	1,38%
2013	386	275		30.742		

Source: EL.STAT for New Registrations

Table A3: Comparisons between total numbers of vehicles in circulation at the end of each year reported by EL.STAT and EMISSIA SA

	PASSENGER CARS			TRUCKS		
Year	**EMISSIA SA**	**EL.STAT**	**Difference**	**EMISSIA SA**	**EL.STAT**	**Difference**
2000	3.312.486	3.195.065	117.421	905.544	1.057.422	151.878
2001	3.522.178	3.423.704	98.474	925.929	1.085.811	159.882
2002	3.718.059	3.646.069	71.990	932.635	1.109.137	176.502
2003	3.883.417	3.839.549	43.868	938.752	1.131.027	192.275
2004	4.097.866	4.073.511	24.355	954.109	1.159.137	205.028
2005	4.303.129	4.303.129	0	967.881	1.186.483	218.602
2006	4.543.016	4.543.016	0	976.141	1.219.889	243.748
2007	4.798.530	4.798.530	0	989.416	1.255.945	266.529
2008	5.023.944	5.023.944	0	997.998	1.289.525	291.527
2009	5.131.960	5.131.960	0	1.018.943	1.302.430	283.487
2010	5.216.873	5.216.873	0	1.026.362	1.318.768	292.406
2011	5.203.599	5.203.591	8	1.027.126	1.321.296	294.170
2012	5.324.556	5.167.557	156.999	1.027.890	1.318.918	291.028
2013	5.226.859	5.124.208	102.651	1.028.654	1.315.836	287.182

	BUSES			MOTORCYCLES		
Year	**EMISSIA SA**	**EL.STAT**	**Differences**	**EMISSIA SA**	**EL.STAT**	**Differences**
2000	23.131	27.037	3.906	668.354	781.361	113.007
2001	24.524	27.115	2.591	679.817	853.366	173.549
2002	25.087	27.247	2.160	703.682	910.555	206.873
2003	25.456	27.139	1.683	707.369	969.895	262.526
2004	26.245	26.780	535	714.549	1.042.605	328.056
2005	26.829	26.829	0	720.352	1.124.172	403.820
2006	26.938	26.938	0	838.922	1.205.816	366.894
2007	27.102	27.102	0	931.527	1.298.688	367.161
2008	27.186	27.186	0	1.023.619	1.388.607	364.988
2009	27.324	27.324	0	1.448.851	1.448.851	0
2010	27.311	27.311	0	1.499.133	1.499.133	0
2011	27.388	27.121	-267	1.509.654	1.534.902	25.248
2012	27.465	26.962	-503	1.520.175	1.556.435	36.260
2013	27.542	26.783	-759	1.530.711	1.568.596	37.885

Table A4: Forecasting models for the number of Heavy Duty Trucks in circulation at the end of each year between 2014 and 2030 for each combination of classification/technology

Fuel type	Technology	Weight	Model	Used period
Gasoline	Conventional	>3.5t	Linear Trend Model	2008-2013
Diesel	Conventional, Rigid	<=7.5t	S-Curve Trend Model	2000-2013
Diesel	Conventional, Rigid	7.5-12t	S-Curve Trend Model	2000-2013
Diesel	Conventional, Rigid	12-14t	S-Curve Trend Model	2000-2013
Diesel	Conventional, Rigid	14-20t	S-Curve Trend Model	2000-2013
Diesel	Conventional, Rigid	20-26t	S-Curve Trend Model	2000-2013
Diesel	Conventional, Rigid	26-28t	S-Curve Trend Model	2000-2013
Diesel	Conventional, Rigid	28-32t	S-Curve Trend Model	2000-2013
Diesel	Conventional, Rigid	>32t	S-Curve Trend Model	2000-2013
Diesel	Euro 1-91/542/EEC Stage 1, Rigid	<=7.5t	Linear Trend Model	2000-2013
Diesel	Euro 1-91/542/EEC Stage 1, Rigid	7.5-12t	Linear Trend Model	2000-2013
Diesel	Euro 1-91/542/EEC Stage 1, Rigid	12-14t	Linear Trend Model	2000-2013
Diesel	Euro 1-91/542/EEC Stage 1, Rigid	14-20t	Linear Trend Model	2000-2013
Diesel	Euro 1-91/542/EEC Stage 1, Rigid	20-26t	Linear Trend Model	2000-2013
Diesel	Euro 1-91/542/EEC Stage 1, Rigid	26-28t	Linear Trend Model	2000-2013
Diesel	Euro 1-91/542/EEC Stage 1, Rigid	28-32t	Linear Trend Model	2000-2013
Diesel	Euro 1-91/542/EEC Stage 1, Rigid	>32t	Linear Trend Model	2000-2013
Diesel	Euro 2-91/542/EEC Stage 2, Rigid	<=7.5t	S-Curve Trend Model	2005-2013
Diesel	Euro 2-91/542/EEC Stage 2, Rigid	7.5-12t	S-Curve Trend Model	2005-2013
Diesel	Euro 2-91/542/EEC Stage 2, Rigid	12-14t	S-Curve Trend Model	2005-2013
Diesel	Euro 2-91/542/EEC Stage 2, Rigid	14-20t	S-Curve Trend Model	2005-2013
Diesel	Euro 2-91/542/EEC Stage 2, Rigid	20-26t	S-Curve Trend Model	2005-2013
Diesel	Euro 2-91/542/EEC Stage 2, Rigid	26-28t	S-Curve Trend Model	2005-2013
Diesel	Euro 2-91/542/EEC Stage 2, Rigid	28-32t	S-Curve Trend Model	2005-2013
Diesel	Euro 2-91/542/EEC Stage 2, Rigid	>32t	S-Curve Trend Model	2005-2013
Diesel	Euro 3-2000 Standards, Rigid	<=7.5t	Double Exponential Method	2002-2013
Diesel	Euro 3-2000 Standards, Rigid	7.5-12t	Double Exponential Method	2002-2013
Diesel	Euro 3-2000 Standards, Rigid	12-14t	Double Exponential Method	2002-2013
Diesel	Euro 3-2000 Standards, Rigid	14-20t	Double Exponential Method	2002-2013
Diesel	Euro 3-2000 Standards, Rigid	20-26t	Double Exponential Method	2002-2013
Diesel	Euro 3-2000 Standards, Rigid	26-28t	Double Exponential Method	2002-2013
Diesel	Euro 3-2000 Standards, Rigid	28-32t	Double Exponential Method	2002-2013
Diesel	Euro 3-2000 Standards, Rigid	>32t	Double Exponential Method	2002-2013
Diesel	Euro 4-2005 Standards, Rigid	<=7.5t	Quadratic Trend Model	2010-2013
Diesel	Euro 4-2005 Standards, Rigid	7.5-12t	Quadratic Trend Model	2010-2013
Diesel	Euro 4-2005 Standards, Rigid	12-14t	Quadratic Trend Model	2010-2013
Diesel	Euro 4-2005 Standards, Rigid	14-20t	Quadratic Trend Model	2010-2013
Diesel	Euro 4-2005 Standards, Rigid	20-26t	Quadratic Trend Model	2010-2013
Diesel	Euro 4-2005 Standards, Rigid	26-28t	Quadratic Trend Model	2006-2013
Diesel	Euro 4-2005 Standards, Rigid	28-32t	Quadratic Trend Model	2010-2013
Diesel	Euro 4-2005 Standards, Rigid	>32t	Quadratic Trend Model	2010-2013
Diesel	Euro 5-2008 Standards, Rigid	<=7.5t	Linear Trend Model	2010-2013
Diesel	Euro 5-2008 Standards, Rigid	7.5-12t	Linear Trend Model	2009-2013
Diesel	Euro 5-2008 Standards, Rigid	12-14t	Linear Trend Model	2009-2013
Diesel	Euro 5-2008 Standards, Rigid	14-20t	Linear Trend Model	2009-2013
Diesel	Euro 5-2008 Standards, Rigid	20-26t	Linear Trend Model	2009-2013
Diesel	Euro 5-2008 Standards, Rigid	26-28t	Linear Trend Model	2009-2013
Diesel	Euro 5-2008 Standards, Rigid	28-32t	Linear Trend Model	2009-2013
Diesel	Euro 5-2008 Standards, Rigid	>32t	Linear Trend Model	2009-2013
Diesel	Conventional, Articulated	14-20t	Double Exponential Method	2000-2013
Diesel	Conventional, Articulated	20-28t	Double Exponential Method	2000-2013
Diesel	Conventional, Articulated	28-34t	Double Exponential Method	2000-2013
Diesel	Conventional, Articulated	34-40t	Double Exponential Method	2000-2013
Diesel	Conventional, Articulated	40-50t	Double Exponential Method	2000-2013
Diesel	Conventional, Articulated	50-60t	Double Exponential Method	2000-2013
Diesel	Euro 1-91/542/EEC Stage 1, Articulated	14-20t	Double Exponential Method	2000-2013
Diesel	Euro 1-91/542/EEC Stage 1, Articulated	20-28t	Double Exponential Method	2000-2013

Table A4 (Continued)

Diesel	Euro 1-91/542/EEC Stage 1, Articulated	28-34t	Double Exponential Method	2000-2013
Diesel	Euro 1-91/542/EEC Stage 1, Articulated	34-40t	Double Exponential Method	2000-2013
Diesel	Euro 1-91/542/EEC Stage 1, Articulated	40-50t	Double Exponential Method	2000-2013
Diesel	Euro 1-91/542/EEC Stage 1, Articulated	50-60t	Double Exponential Method	2000-2013
Diesel	Euro 2-91/542/EEC Stage 2, Articulated	14-20t	S-Curve Trend Model	2005-2013
Diesel	Euro 2-91/542/EEC Stage 2, Articulated	20-28t	S-Curve Trend Model	2005-2013
Diesel	Euro 2-91/542/EEC Stage 2, Articulated	28-34t	S-Curve Trend Model	2005-2013
Diesel	Euro 2-91/542/EEC Stage 2, Articulated	34-40t	S-Curve Trend Model	2005-2013
Diesel	Euro 2-91/542/EEC Stage 2, Articulated	40-50t	S-Curve Trend Model	2005-2013
Diesel	Euro 2-91/542/EEC Stage 2, Articulated	50-60t	S-Curve Trend Model	2005-2013
Diesel	Euro 3-2000 Standards, Articulated	14-20t	Linear Trend Model	2008-2013
Diesel	Euro 3-2000 Standards, Articulated	20-28t	Linear Trend Model	2008-2013
Diesel	Euro 3-2000 Standards, Articulated	28-34t	Linear Trend Model	2008-2013
Diesel	Euro 3-2000 Standards, Articulated	34-40t	Linear Trend Model	2008-2013
Diesel	Euro 3-2000 Standards, Articulated	40-50t	Linear Trend Model	2008-2013
Diesel	Euro 3-2000 Standards, Articulated	50-60t	Linear Trend Model	2008-2013
Diesel	Euro 4-2005 Standards, Articulated	14-20t	Quadratic Trend Model	2006-2013
Diesel	Euro 4-2005 Standards, Articulated	20-28t	Quadratic Trend Model	2006-2013
Diesel	Euro 4-2005 Standards, Articulated	28-34t	Quadratic Trend Model	2006-2013
Diesel	Euro 4-2005 Standards, Articulated	34-40t	Quadratic Trend Model	2006-2013
Diesel	Euro 4-2005 Standards, Articulated	40-50t	Quadratic Trend Model	2006-2013
Diesel	Euro 4-2005 Standards, Articulated	50-60t	Quadratic Trend Model	2006-2013
Diesel	Euro 5-2008 Standards, Articulated	14-20t	Linear Trend Model	2009-2013
Diesel	Euro 5-2008 Standards, Articulated	20-28t	Linear Trend Model	2009-2013
Diesel	Euro 5-2008 Standards, Articulated	28-34t	Linear Trend Model	2009-2013
Diesel	Euro 5-2008 Standards, Articulated	34-40t	Linear Trend Model	2009-2013
Diesel	Euro 5-2008 Standards, Articulated	40-50t	Linear Trend Model	2009-2013
Diesel	Euro 5-2008 Standards, Articulated	50-60t	Linear Trend Model	2009-2013

Table A5: Forecasting models for the number of Light Commercial Vehicles in circulation at the end of each year between 2014 and 2030 for each combination of classification/ technology

Fuel type	Technology	Weight	Model	Used period
Gasoline	Conventional	<3.5t	S-Curve Trend Model	2008-2013
Gasoline	LD Euro 1-93/59/EEC	<3.5t	S-Curve Trend Model	2008-2013
Gasoline	LD Euro 2-96/69/EEC	<3.5t	S-Curve Trend Model	2008-2013
Gasoline	LD Euro 3-98/69/EC Stage 2000	<3.5t	S-Curve Trend Model	2010-2013
Gasoline	LD Euro 4-98/69/EC Stage 2005	<3.5t	Quadratic Trend Model	2009-2013
Gasoline	LD Euro 5- 2008 Standards	<3.5t	Linear Trend Model	2011-2013
Diesel	Conventional	<3.5t	S-Curve Trend Model	2005-2013
Diesel	LD Euro 1-93/59/EEC	<3.5t	S-Curve Trend Model	2005-2013
Diesel	LD Euro 2-96/69/EEC	<3.5t	S-Curve Trend Model	2005-2013
Diesel	LD Euro 3-98/69/EC Stage 2000	<3.5t	Double Exponential Method	2002-2013
Diesel	LD Euro 4-98/69/EC Stage 2005	<3.5t	Quadratic Trend Model	2010-2013
Diesel	LD Euro 5- 2008 Standards	<3.5t	Linear Trend Model	2011-2013

Table A6: Forecasting models for the number of Urban Buses in circulation at the end of each year between 2014 and 2030 for each combination of classification/technology

Fuel type	Technology	Weight	Model	Used period
Diesel	Conventional, Midi	<=15t	S-Curve Trend Model	2008-2013
Diesel	Euro 1-91/542/EEC Stage 1, Midi	<=15t	S-Curve Trend Model	2008-2013
Diesel	Euro 1-91/542/EEC Stage 1, Standard	15-18t	S-Curve Trend Model	2008-2013
Diesel	Euro 1-91/542/EEC Stage 1, Articulated	>18t	S-Curve Trend Model	2008-2013
Diesel	Euro 2-91/542/EEC Stage 2, Midi	<=15t	S-Curve Trend Model	2002-2013
Diesel	Euro 2-91/542/EEC Stage 2, Standard	15-18t	S-Curve Trend Model	2002-2013
Diesel	Euro 2-91/542/EEC Stage 2, Articulated	>18t	S-Curve Trend Model	2002-2013
Diesel	Euro 3-2000 Standards, Midi	<=15t	S-Curve Trend Model	2009-2013
Diesel	Euro 3-2000 Standards, Standard	15-18t	S-Curve Trend Model	2009-2013
Diesel	Euro 3-2000 Standards, Articulated	>18t	Linear Trend Model	2009-2013
Diesel	Euro 4-2005 Standards, Midi	<=15t	Quadratic Trend Model	2006-2013
Diesel	Euro 4-2005 Standards, Standard	15-18t	Quadratic Trend Model	2006-2013
Diesel	Euro 4-2005 Standards, Articulated	>18t	Quadratic Trend Model	2006-2013
Diesel	Euro 5-2008 Standards, Midi	<=15t	Linear Trend Model	2009-2013
Diesel	Euro 5-2008 Standards, Standard	15-18t	Linear Trend Model	2009-2013
Diesel	Euro 5-2008 Standards, Articulated	>18t	Linear Trend Model	2009-2013

Table A7: Forecasting models for the number of Coaches in circulation at the end of each year between 2013 and 2030 for each combination of classification/technology

Fuel type	Technology	Weight	Model	Used period
Diesel	Conventional, Standard	<=18t	S-Curve Trend Model	2007-2013
Diesel	Conventional, Articulated	>18t	S-Curve Trend Model	2007-2013
Diesel	HD Euro 1-91/542/EEC Stage 1, Standard	<=18t	S-Curve Trend Model	2007-2013
Diesel	HD Euro 1-91/542/EEC Stage 1, Articulated	>18t	S-Curve Trend Model	2007-2013
Diesel	HD Euro 2-91/542/EEC Stage 2, Standard	<=18t	S-Curve Trend Model	2005-2013
Diesel	HD Euro 2-91/542/EEC Stage 2, Articulated	>18t	S-Curve Trend Model	2005-2013
Diesel	HD Euro 3-2000 Standards, Standard	<=18t	S-Curve Trend Model	2008-2013
Diesel	HD Euro 3-2000 Standards, Articulated	>18t	S-Curve Trend Model	2008-2013
Diesel	HD Euro 4-2005 Standards, Standard	<=18t	Quadratic Trend Model	2006-2013
Diesel	HD Euro 4-2005 Standards, Articulated	>18t	Quadratic Trend Model	2006-2013
Diesel	HD Euro 5-2008 Standards, Standard	<=18t	Linear Trend Model	2009-2013
Diesel	HD Euro 5-2008 Standards, Articulated	>18t	Linear Trend Model	2009-2013

Table A8: Forecasting models for the number of Motorcycles* and Mopeds** in circulation at the end of each year between 2013 and 2030 for each combination of classification/ technology

Fuel type	Technology	Displacement	Model	Used period
Gasoline*	Conventional, 4 stroke	<250 cm^3	S-Curve Trend Model	2000-2013
Gasoline*	Conventional, 4 stroke	250-750 cm^3	S-Curve Trend Model	2000-2013
Gasoline*	Conventional, 4 stroke	>750 cm^3	S-Curve Trend Model	2009-2013
Gasoline*	Euro 1, 4 stroke	<250 cm^3	S-Curve Trend Model	2004-2013
Gasoline*	Euro 1, 4 stroke	250-750 cm^3	S-Curve Trend Model	2004-2013
Gasoline*	Euro 1, 4 stroke	>750 cm^3	S-Curve Trend Model	2004-2013
Gasoline*	Euro 2, 4 stroke	>50 cm^3	S-Curve Trend Model	2014-2018
Gasoline*	Euro 2, 4 stroke	250-750 cm^3	S-Curve Trend Model	2014-2018
Gasoline*	Euro 2, 4 stroke	>750 cm^3	S-Curve Trend Model	2014-2018
Gasoline*	Euro 3, 4 stroke	>50 cm^3	Linear Trend Model	2008-2013
Gasoline*	Euro 3, 4 stroke	250-750 cm^3	Linear Trend Model	2008-2013
Gasoline*	Euro 3, 4 stroke	>750 cm^3	Linear Trend Model	2009-2013
Gasoline**	Conventional	<50 cm^3	S-Curve Trend Model	2006-2013
Gasoline**	Euro 1	<50 cm^3	S-Curve Trend Model	2011-2013

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