Study on the impacts of LPG cars penetration in EU31 on the exhaust air emission reduction

FINAL REPORT

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Abstract
The European LPG Association (AEGPL) has commissioned a study, estimating the benefits of increasing the share of LPG-fuelled cars within the EU car-fleet. More specifically, the study analyses the potential of LPG cars to contribute to reducing exhaust emissions of CO2 and a series of pollutants, including PM, NOx, CO and HC, which constitute a significant threat to human health. Three scenarios - a reference case as well as two more optimistic projections - for LPG car penetration have been simulated based on the TREMOVE model and database as updated by with information furnished by AEGPL. The stronger penetration rate of LPG cars is assumed to result from both the retrofitting of conventional cars and the manufacturing of new built LPG vehicles. This study demonstrates that increasing the penetration rate of LPG cars in Europe would result in a significant reduction in emissions of CO2 and a series of major pollutants.

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1. Introduction

The implementation of an appropriate public policy at European, national and local level is an essential step in promoting the emergence of LPG as an automotive fuel. Such an evolution would yield numerous important benefits including improvement of urban air quality and the reduction of CO2 emissions from transport.

AEGPL [2007] The LPG Industry Roadmap has identified three key types of initiative which should be taken to promote the use of LPG as an automotive fuel:

- Encouraging consumers to switch from conventional fuels to clean alternatives such as LPG
- Stimulating the modification (retrofitting) of existing vehicles from petrol-fuelled to LPG fuelled
- Encouraging carmakers to place new vehicles powered by LPG, mono-fuel, bi-fuel (LPG/petrol, LPG/biofuel) or hybrid (LPG/electric) on the market.

This study aims to quantify some of the benefits that would result from an increase in the share of LPG-powered cars in the European fleet, notably as regards exhaust emissions of CO2 and several key pollutants typically associated with the automotive sector. Among the important cost elements taken into account in the calculation are the additional retrofitting costs to LPG cars and the lower LPG fuel prices compared to the conventional fuel prices. This analysis is undertaken via three scenarios for the evolution of LPG's share in the fuel mix up to 2020. Ref Scenario is a reference case, wherein little or no change from the current situation is anticipated. Optimistic scenarios of 1 and 2 both foresee an increasing role for LPG. The anticipated growth can be assumed to be driven by a combination of factors, including the establishment of a more favourable public policy framework, and a sustained commitment to development on the part of the LPG industry and car manufacturers.

2. Methodology, assumptions, and sources

2.1 Methodology of the calculation

The basis of the study is the TREMOVE model (TML [2007]). TREMOVE is a policy assessment model used to study the effects of different transport and environment policies on the emissions of the transport sector. Developed for the European Commission (DG TREN) in 1997, TREMOVE provides the "back-bone" of the ad-hoc model developed for this project. It furnishes the ad-hoc model with most of the modelling principles, assumptions, and data.

TREMOVE predicts the overall emissions from the transport sector in different policy scenarios. The strength of the model is that it also allows for the assessment of the effects of environmental policies on future vehicle fleets and on overall transport demand and its modal split. The calculated welfare effect of a policy is not only determined by technology costs and emission reductions, but also by effects on household mobility, industry logistic processes and government tax income from the transport sector. The model can be applied for environmental and economic analysis of different policies including road pricing, public transport pricing, emission standards, subsidies for cleaner cars etc. TREMOVE models both passenger and freight transport in 31 European countries, and covers the period 1995-2020, with yearly intervals.

Table 2.a 31 European countries covered by TREMOVE model

AT	Austria	FR	France	NO	Norway
BE	Belgium	GR	Greece	PL	Poland
BG	Bulgaria	HR	Croatia	PT	Portugal
CH	Switzerland	HU	Hungary	RO	Romania
CY	Cyprus	IE	Ireland	SE	Sweden
CZ	Czech Republic	IT	Italy	SI	Slovenia
DE	Germany	LT	Lithuania	SK	Slovakia
DK	Denmark	LU	Luxemburg	TR	Turkey
EE	Estonia	LV	Latvia	UK	United Kingdom
ES	Spain	MT	Malta		
FI	Finland	NL	The Netherlands		

An ad-hoc model has been developed in the VENSIM© system dynamic environment in order to perform the simulations presented in this study. The ad-hoc model uses elements from the four modules of the TREMOVE model: transport demand, vehicle stocks, emissions and welfare modules. Databases, assumptions, and modelling principles are used in the four modules, particularly as regards the following conventional car technologies:

- Small diesel, gasoline, and CNG cars (<1.4l)
- Medium diesel, gasoline, and CNG cars (between 1.4 and 2.0l)
- Big diesel, gasoline, and CNG cars (>2.0l)

The TREMOVE model also includes one category of LPG car (1.4l or larger), and contains the assumptions and data required to model the fleet development of this car type. However, with a view to optimizing the reliability of the results of this study, some exogenous assumptions - including penetration rates for LPG-fuelled cars, data on LPG car stocks, and costs provided by AEGPL - have been incorporated.

The combination of assumptions, data and modelling elements from TREMOVE, AEGPL and other sources in the ad-hoc model as well as the associated outputs is summarized in Figure 1.

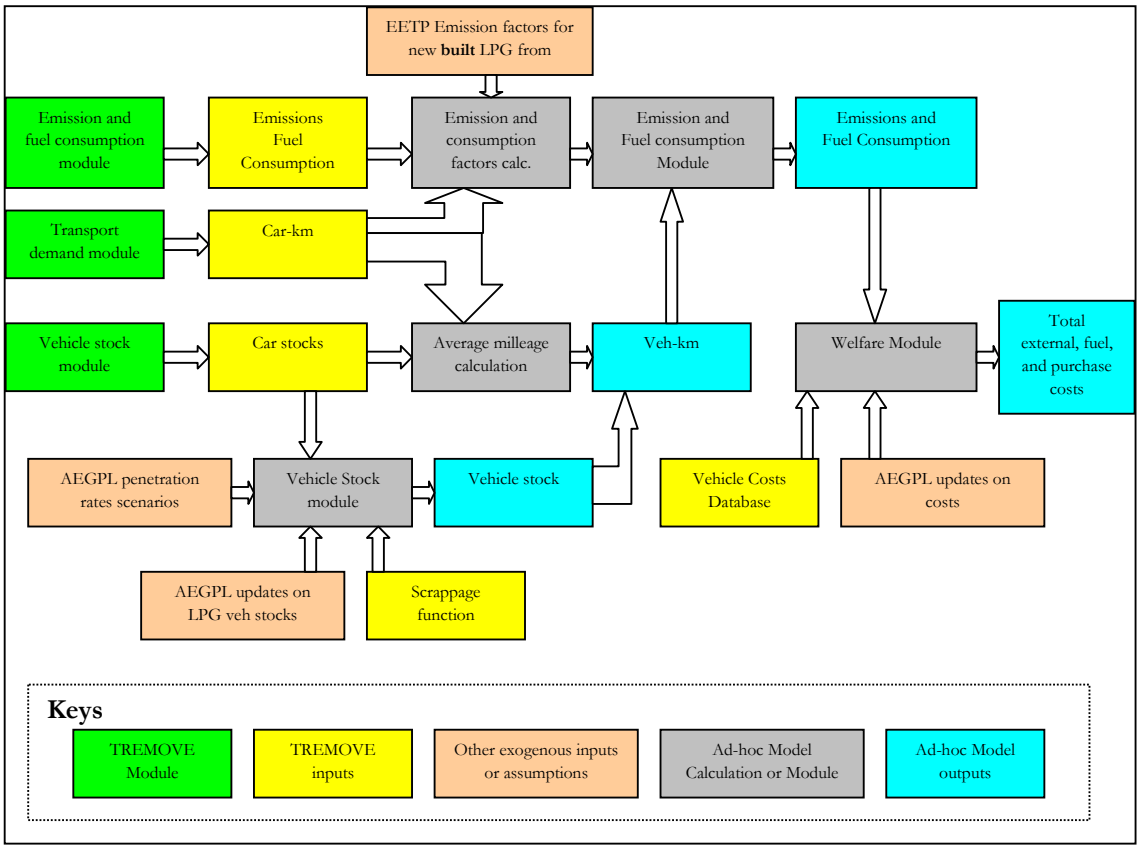

Figure 1 Structure of Modelling Work

Using 2007 as the base year and producing outcomes to the horizon of 2020, the ad-hoc model can be split into three modules:

- **Vehicle stock module** which takes inputs of conventional car stocks, sales, scrappage functions from TREMOVE as well as LPG car stocks and penetration assumption from AEGPL in order to estimate the development of vehicle stocks during the observed period. The number of vehicles (cars) obtained from this module is then multiplied by the average mileage, as foreseen by TREMOVE.
- **Emission and fuel consumption module** which calculates the fuel consumption and emissions of several key pollutants based on average emission factors and fuel efficiency calculated using inputs from TREMOVE and from external sources.
- **Welfare module** which calculates the total costs of car purchasing, fuel consumption, and externalities linked to emissions. The TREMOVE model contains a module of welfare aiming at assessing the difference in social welfare among different scenarios. In TREMOVE, the difference in social welfare is calculated as the sum of 4 components: (i) change in utility of household, (ii) change in production costs, (iii) change in external effects, and (iv) distortion effect of changes in taxes and subsidies. These four components are expressed in monetary terms which permit the calculation of a global level of social welfare. Apart from the income, the first component calculates the difference in the household consumption and production surplus (CS and PS) between the simulated and the baseline scenarios while the second component calculates the difference in the firms CS and PS between the simulated and the baseline scenario. The first and second components costs include costs for *vehicle purchase*, *maintenance*, and *fuel*. The third component, the external effects, concerns mainly the change between the simulated and baseline scenarios in *congestion* and *environmental* costs. The forth component, the distortion effect of

changes in taxes and subsidies, concerns the distortion effect of taxes, (such as the *VAT*, *excise duty*, etc.) and subsidies on the total social welfare.

The "welfare module" of the ad-hoc model does not fully replicate the welfare module of the TREMOVE model. It calculates only the cost elements determining the change of households and firms utility, i.e. *car purchase costs* and *fuel costs*, one cost element of the external effect, i.e. *environmental costs*, two element of taxes, i.e. *fuel excise duty* and *fuel VAT*, and it assumes that those *taxes levied by the government will be fully returned in one way or another to the users (households and firms)*. The ad-hoc model calculates *the total final costs* as the sum of the car purchase costs, fuel resource costs and external costs and it calculates also the *cost effectiveness* in relation to the number of tons of avoided CO2 emissions.

The ad-hoc model does not estimate the choice of users among the different vehicle types. The initial share of the different vehicle (car) types is taken from TREMOVE and the dynamic of this share is affected only by to the penetration of the LPG cars given as assumptions in the scenarios for the whole period.

2.2 Overview of the assumptions

The most important assumptions concern the penetration rate of LPG cars. AEGPL provides the penetration rate of medium and big LPG cars (equal or bigger than 1.4l) and of small LPG cars (>1.4l) for each of the 31 European countries using the template shown in the Table 2.b.

Table 2.b Template of LPG car penetration rates assumption for one country

Car type of Origin	Nature of new LPG car	2008 – 2020				
car >2.0l – diesel	NEW					
car >2.0l – diesel	RETROFIT	0	0	0	0	0
car 1.4-2.0l – diesel	NEW					
car 1.4-2.0l – diesel	RETROFIT	0	0	0	0	0
car <1.4l – diesel	NEW					
car <1.4l – diesel	RETROFIT	0	0	0	0	0
car >2.0l – petrol	NEW					
car >2.0l – petrol	RETROFIT					
car 1.4-2.0l – petrol	NEW					
car 1.4-2.0l – petrol	RETROFIT					
car <1.4l – petrol	NEW					
car <1.4l – petrol	RETROFIT					

The increased penetration of LPG-fuelled cars is to be achieved through both the retrofitting of existing petrol-fuelled cars and the emergence of new-build LPG cars. The number of new LPG cars in the year *t* is obtained by multiplying the penetration rates by the number of corresponding conventional cars sold in the previous year.

For small (<1.4l), medium and large (≥1.4l) LPG cars, this figure is obtained via the following two equations:

$$NCR_{country,LPG<1.4l,nature,t} = \sum_{car\_type<1.4l} pr_{country,car\_type<1.4l,nature,t} \times NCR_{country,car\_type<1.4l,nature,t-1} \quad (1)$$

$$NCR_{country,LPG\geq1.4l,nature,t} = \sum_{car\_type\geq1.4l} pr_{country,car\_type\geq1.4l,nature,t} \times NCR_{country,car\_type\geq1.4l,nature,t-1} \quad (2)$$

where

NCR : *number of new car*
t : *year (2008 to 2020)*
country : *country (31 European countries of TREMOVE)*
nature : *nature of LPG cars origin (retrofitting and new built)*
car_type<1.4l : *small conventional car types (diesel<1.4l, petrol<1.4l)*
car_type≥1.4l : *medium and big conventional car types (diesel between 1.4l and 2l, petrol between 1.4l and 2l, diesel>2l, petrol>2l)*

In the TREMOVE model, LPG cars are only represented by one vehicle type, i.e. those with engines of 1.4l or larger. The assumptions made in this study on the penetration (introduction) of small LPG cars (<1.4l) through retrofitting of small conventional cars and from new building of small LPG cars in Europe permit the inclusion of the small LPG car (1.4l) as a new vehicle type in the ad-hoc model.

The penetration rates are given in two different scenarios: *scenario 1* and *scenario 2*. Scenario 1 was initially developed to reflect a reference scenario where the total share of LPG cars in Europe would reach 3% of the total car fleet by 2020, reflecting a stable penetration-rate over the 2007-2020 period. Scenario 2 was initially built on the assumption of stronger penetration rates for this same period of time aiming at having a passenger car share by 2020 of:

- 3% in Switzerland, Denmark, Finland, Greece, Ireland, Norway, Sweden, Cyprus, and Malta,
- 7.5% in Austria, Spain, France, Luxembourg, United Kingdom, Slovenia, and Slovakia,
- 10% in Belgium, Germany, Italia, Latvia, Estonia, Serbia Montenegro, Hungary, and Portugal,
- 12.5% in Czech Republic, the Netherlands, and Romania, and
- 15% in Bulgaria, Lithuania, Poland, and Turkey.

Both scenarios have been based on calculation and expert estimation made by AEGPL.

After the preliminary model runs, the results for Scenario 2 were in line with the expected target, while scenario 1 actually exceeded the expected Reference penetration reaching 7.65%. A third scenario (*Scenario REF*), in which LPG achieved a penetration rate of 3% was therefore developed. The detailed results of these three scenarios are presented in Section 3 of this study.

2.3 Justification with applied sources

The data used comes from three different sources: TREMOVE model, AEGPL, and other external sources.

The most important and relevant inputs from TREMOVE model are extracted from the baseline simulation run of the model reported in TML [2007]. The development of the TREMOVE baseline involved the construction of a coherent reference case for transport demand, vehicle stocks and emissions. This reference case has been developed for all countries and model regions considered. It includes every year from the base year 1995 until 2030. The baseline transport volumes have been extracted to a large extent from the SCENES transport model, and further calibrated towards national statistics. Starting from the transport demand forecasts and 1995-2005[1] vehicle stock data, the sales and scrappage models in the vehicle stock turnover module have been used to allocate transport volumes to specific vehicle types for all modes. Next, the fuel consumption and emissions module has been run to forecast the emissions and energy consumption in the baseline scenario. The total fuel consumption in each country is again compared with statistics, and adjustments to the input data were made to the extent possible.

Table 2.c shows the most relevant data source taken from TREMOVE model to produce the input for the baseline scenario. For more detailed discussion on data sources, assumptions, and modelling principles of TREMOVE, please contact TML (details at the top of this study).

[1] The actual years vary between countries and transport modes depending on the data availability

Table 2.c Relevant inputs from TREMOVE model and the corresponding sources

Inputs	Sources[2]
Transport demand (veh-km)	Transport demand in veh-km is calculated based on pass-km obtained from SCENES Partial A model run for the ASSESS project, September 2005 (TML[2007] annex D: Converting SCENES output into the TREMOVE structure) and the fixed occupancy rates from SCENES model (based on UK National Travel Survey and data collected for 2001-2003 from different Member States).
Cost components: - Vehicle purchase cost - Fuel resource cost - Fuel excise duty - Fuel VAT - External costs of pollutants	SCENES Model: vehicle purchase cost from COWI study, fuel resource cost, fuel excise duty, and fuel VAT from PRIMES model run conducted especially for the update of TREMOVE version 3 (March 2007). Values for external costs per ton pollutant have been taken from the cost-benefit analysis (CBA) in the CAFE or *Clean Air For Europe* program except for CO values. The external costs of CO have been taken from ExternE.
Vehicle stock	For the EU15, TRENDS Project for the TREMOVE base year of 1995. Exogenous car market shares figures for 1996-2005 for the small petrol and diesel car types are included based on the most recent data available from the ACEA website, the CO2 voluntary agreement monitoring reports, and from TNO, IEEP, LAT [July, 2006]. For the rest of the European countries, vehicle fleet data has been collected from the different sources including EUROSTAT, National statistical offices of the countries, UNECE Transport division, IRF World Road Statistics, CORINAIR.
Scrappage rate	TRENDS
Emission and fuel consumption	TREMOVE model calculation based on COPERT 4 Methodology

In order to increase the reliability and validity of the results, the elements taken from TREMOVE model are supplemented with data from the AEGPL on LPG-fuelled cars in 2006 and 2007. The corresponding data are summarized in the Table 2.d.

[2] Sources shown in this table concern only the principle data sources used in TREMOVE model. More specific data sources used for calibration purpose at country level, for example: calibration for the purpose of the National Emissions Ceilings (NEC) are given in detailed in the TML[2007]

Table 2.d Relevant inputs provided by AEGPL and the corresponding sources

Inputs	Sources
LPG vehicle stocks 2006, 2007	AEGPL auto gas data
Fuel excise duty	EU-DG TAXUD[2008]: Excise Duty Tables – Part II Energy products and electricity REF 1.026 rev.1 January 2008
Fuel VAT	EU-DG TAXUD[2008]: Excise Duty Tables – Part II Energy products and electricity REF 1.026 rev.1 January 2008
Fuel resource costs	Fuel resource costs from Platt's of the years 2005-2007 have been provided. The average of the three year value is calculated for the whole EU-31 region and this value is used as the base year (2007) value of fuel resource costs. The average growth rate of fuel resource cost from PRIMES (which is used in TREMOVE) is used to have the variation of the costs during the period 2008-2020.
Additional cost of LPG cars (compared to gasoline cars)	AEGPL auto gas data
Emission factors for new built LPG cars	Jeuland, N., Montagne, X. [2004]: EETP (European Emission Test Programme) – Final Report. Considering the wide range of results from EETP study and also for the sake of simplicity, the assumption of the emission factors on LPG cars taken from this study is based only on the comparison LPG/petrol and to choose the highest reduction (or the lowest increase) within these values (kind of "expert judgment").

3. Results

3.1 Fleet development and shares

The TREMOVE model estimates an increase of 27.9% of the total car fleet in EU31 between 2007 and 2020. This means an increase from the current 243.5 million cars to around 311.4 million in 2020; an average increase of 1.9% per year. The total number of cars is identical in all scenarios since the addition of new LPG-powered cars is always assumed to coincide with a corresponding reduction in the number of new conventional cars.

As mentioned in section 2.2, a third scenario has been developed to serve as the "reference scenario" or "scenario REF". In this scenario, the target of a 3% share by 2020 is met exactly. The penetration rate for this scenario is obtained by multiplying the penetration rate of the scenario 1 by a factor of 0.24.. Figure 2 shows the shares of LPG cars (small (<1.4l), medium and big (≥1.4l)) in the 31 countries in Europe for all three scenarios, while Table 3.a gives the detailed share of these cars according to their size.

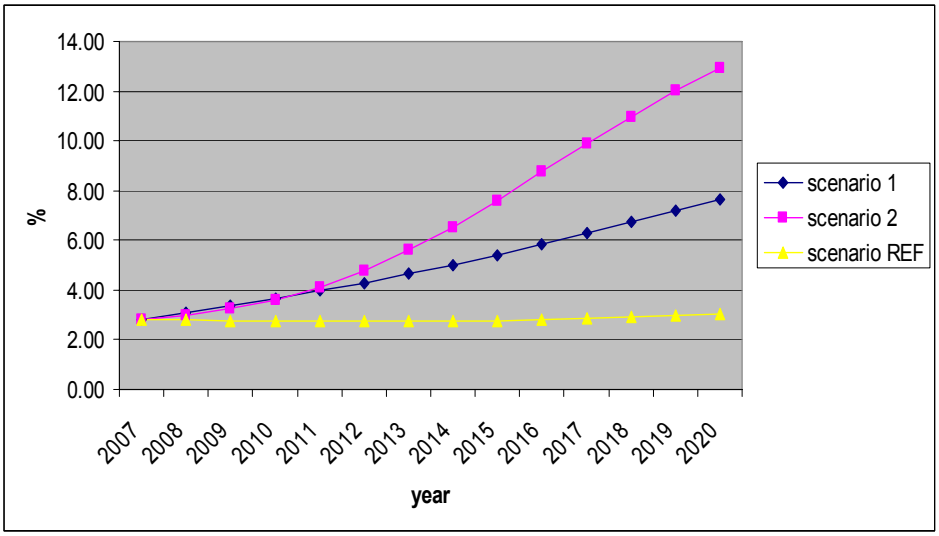

Figure 2 Shares (%) of LPG cars

Table 3.a Detailed shares (%) of LPG cars

Year	scenario REF			scenario 1			scenario 2		
	small LPG cars	Medium and big LPG cars	All LPG cars	small LPG cars	Medium and big LPG cars	All LPG cars	Small LPG cars	Medium and big LPG cars	All LPG cars
2007	1.42	1.41	**2.82**	1.42	1.41	**2.82**	1.42	1.41	**2.82**
2008	1.39	1.40	**2.79**	1.56	1.54	**3.10**	1.55	1.46	**3.01**
2009	1.37	1.39	**2.76**	1.71	1.67	**3.38**	1.72	1.55	**3.27**
2010	1.36	1.39	**2.75**	1.86	1.81	**3.67**	1.95	1.68	**3.63**
2011	1.35	1.38	**2.73**	2.01	1.95	**3.97**	2.25	1.87	**4.12**
2012	1.34	1.39	**2.73**	2.19	2.11	**4.29**	2.63	2.17	**4.80**
2013	1.34	1.39	**2.73**	2.37	2.27	**4.64**	3.06	2.55	**5.61**
2014	1.34	1.40	**2.75**	2.57	2.44	**5.01**	3.52	3.01	**6.54**
2015	1.36	1.42	**2.77**	2.78	2.63	**5.41**	4.03	3.55	**7.58**
2016	1.38	1.44	**2.81**	3.02	2.83	**5.85**	4.59	4.17	**8.76**
2017	1.40	1.46	**2.85**	3.25	3.03	**6.28**	5.08	4.81	**9.90**
2018	1.42	1.48	**2.91**	3.49	3.25	**6.74**	5.51	5.47	**10.99**
2019	1.45	1.51	**2.96**	3.74	3.46	**7.20**	5.86	6.16	**12.03**
2020	1.48	1.53	**3.01**	3.99	3.66	**7.65**	6.12	6.84	**12.96**

In absolute numbers, the total number of LPG-fuelled cars in scenario REF is expected to grow from 6.9 millions in 2007 to 9.4 millions in 2020, meaning an increase of 36.5% over 13 years. The estimated number of LPG-powered cars in 2020 for Scenario 1 is 23.8 millions, while 40.3 millions are anticipated in Scenario 2. These projections constitute increases of 3.5 and 5.9-fold respectively.

Figure 3 shows the penetration of new cars (Euro 5 and Euro 6) into the market in Europe 31. As the new LPG cars are assumed to be built or to be retrofitted from the conventional cars, the total number of cars in the model as well as the yearly new registered cars is the same for the three scenarios and these values correspond to the baseline scenario of TREMOVE model being used. The total number of cars in the EU31 in this baseline increase from around 243 millions of cars in 2007 to around 311.4 millions of cars in 2020, corresponds to almost 28% of increase in 14 year period.

At 2010, Euro5 cars enter the EU31 market and immediately represent around 7.5% (19.4 million cars) of the total car population. The share of Euro5 cars increases to more than half of the total car population (147.3 million cars) by 2016 before it decreases in the next four years, reaching around 45.7% of the total car share by 2020, following the introduction of Euro6 cars in 2016 (as shown in the Figure 3). Euro6 cars are assumed to enter the market in 2017 representing around 8.4% of total cars in that year (24.6 million cars) and increase to reach a share of 31.8% by 2020 (99 million cars) [3].

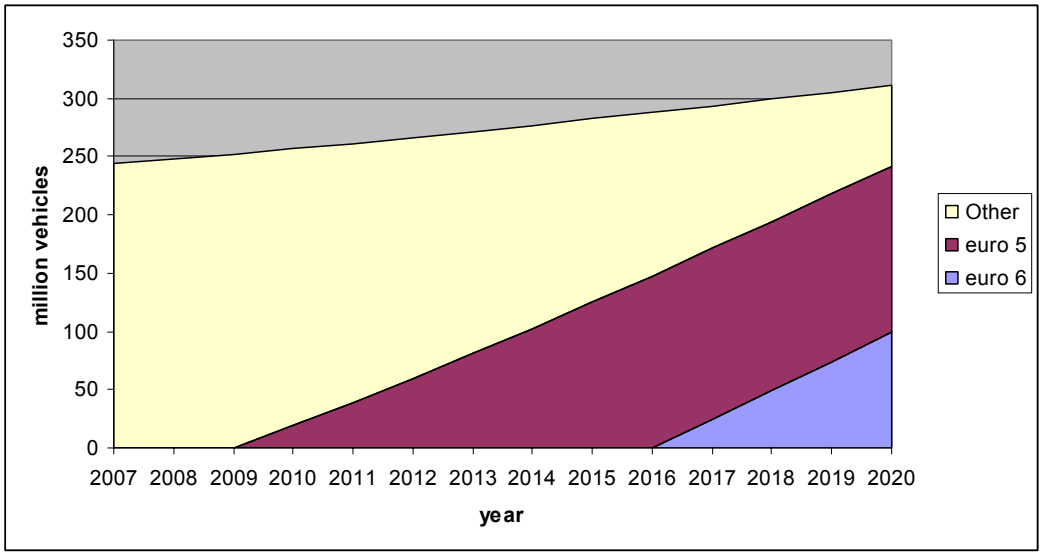

Figure 3 Penetration of new cars (Euro 5 and 6) into the stock

3.2 Fuel consumption and emissions

According to scenario REF, the total fuel consumption of cars in the EU31 increases from the current figure of 196.3 million tons of oil equivalent (toe) to around 212.9 million toe in 2020 which corresponds to 8.4% of increase during 13 years. The projected increase in the penetration of LPG-fuelled cars in the total car fleet between 2007 and 2020 generates only a marginal reduction of total fuel consumption. Scenario 1 foresees a reduction in total fuel consumption by roughly 0.02%, while a reduction of 0.08% is projected in Scenario 2.

In Scenario REF, LPG accounts for 1.78% of total car fuel consumption in the EU 31 in 2020. Scenario 1 foresees a share of 4.54% while Scenario 2 shows a share of 10.50% (Table 3.b). This is consistent with the projected share of LPG-fuelled cars within the total fleet as shown in the previous section, i.e. 3.01%, 7.65, and 12.96% for Scenarios REF, 1, and 2 respectively. This finding demonstrates that the share of LPG within the fuel mix increases more slowly than the share of LPG-powered cars.

[3] Euro5 and Euro6 cars scrapped over the period are also taken into account in this fleet development

Table 3.b Detailed shares (%) of fuel consumption of LPG cars

Year	scenario REF			scenario 1			scenario 2		
	small LPG cars	Medium and big LPG cars	All LPG cars	Small LPG cars	Medium and big LPG cars	All LPG cars	small LPG cars	Medium and big LPG cars	All LPG cars
2007	0.66	1.10	**1.76**	0.66	1.10	**1.76**	0.66	1.10	**1.76**
2008	0.64	1.09	**1.74**	0.72	1.21	**1.93**	0.74	1.17	**1.91**
2009	0.63	1.09	**1.72**	0.78	1.32	**2.10**	0.85	1.27	**2.12**
2010	0.62	1.08	**1.70**	0.85	1.44	**2.28**	0.98	1.42	**2.40**
2011	0.61	1.08	**1.69**	0.91	1.55	**2.47**	1.16	1.64	**2.80**
2012	0.60	1.08	**1.68**	0.99	1.68	**2.66**	1.40	1.96	**3.36**
2013	0.60	1.08	**1.68**	1.06	1.81	**2.87**	1.66	2.38	**4.04**
2014	0.60	1.08	**1.68**	1.14	1.94	**3.09**	1.95	2.89	**4.84**
2015	0.60	1.09	**1.69**	1.23	2.09	**3.31**	2.25	3.47	**5.72**
2016	0.60	1.10	**1.70**	1.32	2.24	**3.56**	2.57	4.13	**6.70**
2017	0.61	1.11	**1.72**	1.41	2.39	**3.80**	2.85	4.82	**7.67**
2018	0.61	1.12	**1.74**	1.50	2.55	**4.05**	3.10	5.53	**8.63**
2019	0.62	1.14	**1.76**	1.60	2.70	**4.30**	3.31	6.28	**9.59**
2020	0.63	1.15	**1.78**	1.69	2.85	**4.54**	3.47	7.03	**10.50**

Each scenario includes calculations of tank-to-wheel (exhaust) emissions of five key pollutants/emissions: CO2, CO, HC, NOx, and PM2.5. The scenarios demonstrate that an increased presence of LPG in the European fuel mix would have a substantial impact on emissions. Table 3.c shows that Scenarios 1 and 2 would both lead to a reduction of total cumulative emissions during the observed period. Scenario 2, in which LPG exhibits particularly strong growth, yields particularly positive results.

Table 3.c Change in percent, in tonnes and MEuros in cumulative emissions during the period of 2007 to 2020 in comparison to the reference scenario

	% (tonnes)		Mtonnes		% (Meuros)		MEuros	
	scenario 1	scenario 2	scenario 1	scenario 2	scenario 1	scenario 2	scenario 1	scenario 2
CO	-1.20	-2.35	-0.49	-0.95	-0.93	-2.21	-2.16	-5.14
CO2	-1.40	-3.65	-121.09	-314.81	-1.60	-4.30	-5130.93	-13812.51
HC	-1.12	-2.26	-0.06	-0.11	-1.08	-2.48	-110.17	-253.61
NOX	-0.81	-2.61	-0.10	-0.34	-0.78	-2.75	-1113.50	-3909.83
PM	-0.72	-2.46	0.00	-0.01	-0.66	-2.56	-216.09	-834.43

3.3 Costs

3.3.1 Car purchase costs

In comparison to Scenario REF, the total accumulated car purchase costs without tax from 2007 to 2020 are increased by 0.38% in Scenario 1 and by 1.18% in Scenario 2. In absolute terms, these correspond to €18.9 and €59.4 billion respectively. **Euro values used in this study always correspond to the value of Euro of the year 2000**. Purchases of big and medium LPG cars (≥1.4l) are projected to increase by more than four-fold projected in Scenario 1 and more than eleven-fold in Scenario 2. Purchases of small LPG cars (<1.4l) are expected to increase by more than four-fold in Scenario 1 and more than 8.5-fold in Scenario 2 (Table 3.d).

The increase in accumulated small LPG purchase costs corresponds directly to the decreasing number of small conventional (petrol and diesel) car purchase costs. The accumulated car purchase costs decreases in all small conventional cars in Scenarios 1 and 2. In both Scenarios 1 and 2 the reduction in spending is expected to affect the small petrol market more than the small diesel market.

The increase in the accumulated car purchase costs of medium and big LPG cars (>1.4l) corresponds directly to the reduction of the accumulated car purchase costs for the corresponding conventional (petrol and diesel) cars. In Scenario 1, the reduction of total spending on medium and big petrol cars is greater than the reduction in money spent on medium and big diesel cars. In Scenario 2, the opposite is the case. Conclusion: In Scenario 1, there is a tendency toward shifting away from medium and big petrol cars towards LPG-fuelled cars, while Scenario 2 projects a stronger shift away from medium and big diesel cars in favour of LPG-powered equivalents.

Table 3.d Change (%) in the accumulated car purchase costs without tax from 2007 to 2020 compared to the reference scenario

	%		Meuros	
Car type	**Scenario 1**	**Scenario 2**	**Scenario 1**	**Scenario 2**
small petrol (<1.4l)	-6.05	-14.14	-52391.18	-122372.23
medium petrol (1.4l - 2.0l)	-3.99	-6.08	-46670.02	-71059.77
big petrol (>2.0l)	-2.22	0.70	-12632.72	3989.31
small diesel (<1.4l)	-1.11	-8.94	-1810.83	-14561.71
medium diesel (1.4l - 2.0l)	-2.03	-11.16	-30736.91	-168972.12
big diesel (>2.0l)	-1.39	-12.23	-9366.54	-82550.78
lpg (>1.4l)	307.55	1004.14	109821.05	358565.44
small lpg (<1.4l)	302.38	754.17	62687.51	156347.97
Total	**0.38**	**1.18**	**18900.36**	**59386.11**

Small problem in this study lies in the fact that no modal choice is simulated. Penetration rate is fixed and this is the only factor that determines the share of fleets in the whole observed period. TREMOVE purchase costs data is taken from COWI study (COWI [2001]). According to this study, the average prices of small petrol car are smaller than those of the corresponding small diesel while the average prices of medium and big petrol are higher than that those of the corresponding medium and big diesel. The latter fact makes that the average prices of the medium and big LPG cars coming from the shift from medium and big petrol car users, which are obtained by adding some fixed extra costs to the corresponding petrol car prices, are becoming higher than the average prices of medium and big diesel cars. Table 3.e gives the illustration of these purchase costs for the reference scenario in 2010 and 2020. The average prices of LPG (medium and big) cars are in average 3300 euros and 2800 euros more expensive than those of medium diesel cars in 2010 and 2020 respectively.

According to the COWI data, the price situation will hinder users from shifting from medium and big diesel cars to medium and big LPG cars However, today's market reality shows that LPG powered vehicles are competing with diesel-powered vehicles, meaning that car purchase costs tend to be equal between those two fuels. It should be noted that the additional cost of the LPG feeding systems is assumed to be the same over the 2007-2020 period. Looking at scenario 2, which foresees a greater uptake of factory-fitted LPG cars, this additional cost could be significantly reduced thanks to economies of scale. Although these statements are intuitively accurate, they cannot be backed with data; therefore this effect was not taken into account in this study.

Table 3.e Average purchase cost (euros) of cars without VAT based on scenario REF[4]

[Country, vehicle type]	2010	2020	[Country, vehicle type]	2010	2020	[Country, vehicle type]	2010	2020
[AT,small petrol]	10303	10965	[IT,small petrol]	9311	9909	[EE,small petrol]	5624	5986
[AT,medium petrol]	17106	18206	[IT,medium petrol]	18523	19714	[EE,medium petrol]	10407	11076
[AT,big petrol]	35221	37485	[IT,big petrol]	45271	48181	[EE,big petrol]	19872	21150
[AT,small diesel]	11581	12243	[IT,small diesel]	10589	11187	[EE,small diesel]	6902	7264
[AT,medium diesel]	16401	17455	[IT,medium diesel]	16782	17861	[EE,medium diesel]	10373	11039
[AT,big diesel]	27720	29502	[IT,big diesel]	30449	32407	[EE,big diesel]	17949	19103
[AT,lpg]	21632	23253	[IT,lpg]	25669	27468	[EE,lpg]	13684	14497
[AT,small lpg]	11729	12391	[IT,small lpg]	10783	11381	[EE,small lpg]	6999	7361
[BE,small petrol]	9525	10138	[LU,small petrol]	9828	10460	[HR,small petrol]	5624	5986
[BE,medium petrol]	16931	18020	[LU,medium petrol]	17367	18484	[HR,medium petrol]	10407	11076
[BE,big petrol]	35074	37330	[LU,big petrol]	37455	39863	[HR,big petrol]	19872	21150
[BE,small diesel]	10803	11416	[LU,small diesel]	11106	11738	[HR,small diesel]	6902	7264
[BE,medium diesel]	15766	16780	[LU,medium diesel]	16307	17355	[HR,medium diesel]	10373	11039
[BE,big diesel]	28017	29819	[LU,big diesel]	28520	30353	[HR,big diesel]	17949	19103
[BE,lpg]	20933	22445	[LU,lpg]	23371	25638	[HR,lpg]	12439	13225
[BE,small lpg]	11103	11716	[LU,small lpg]	11466	12095	[HR,small lpg]	6774	7136
[CH,small petrol]	10895	11596	[NL,small petrol]	8282	8814	[HU,small petrol]	5835	6210
[CH,medium petrol]	19528	20784	[NL,medium petrol]	13464	14330	[HU,medium petrol]	10797	11491
[CH,big petrol]	37616	40034	[NL,big petrol]	27750	29534	[HU,big petrol]	20617	21943
[CH,small diesel]	12173	12874	[NL,small diesel]	9560	10092	[HU,small diesel]	7113	7488
[CH,medium diesel]	20661	21989	[NL,medium diesel]	13692	14572	[HU,medium diesel]	10761	11453
[CH,big diesel]	30459	32418	[NL,big diesel]	26131	27811	[HU,big diesel]	18622	19819
[CH,lpg]	27640	30141	[NL,lpg]	16869	18044	[HU,lpg]	12500	13251
[CH,small lpg]	12263	12963	[NL,small lpg]	9775	10308	[HU,small lpg]	6835	7210
[DE,small petrol]	12580	13388	[NO,small petrol]	9305	9903	[LT,small petrol]	5624	5986
[DE,medium petrol]	21152	22512	[NO,medium petrol]	10225	10882	[LT,medium petrol]	10407	11076
[DE,big petrol]	41191	43839	[NO,big petrol]	19524	20779	[LT,big petrol]	19872	21150
[DE,small diesel]	13858	14666	[NO,medium diesel]	13632	14509	[LT,small diesel]	6902	7264
[DE,medium diesel]	21085	22441	[NO,big diesel]	17635	18768	[LT,medium diesel]	10373	11039
[DE,big diesel]	33525	35680	[NO,lpg]	12268	13089	[LT,big diesel]	17949	19103
[DE,lpg]	28137	30291	[NO,small lpg]	10680	11278	[LT,lpg]	13715	14530
[DE,small lpg]	14205	15014	[PT,small petrol]	10528	11205	[LT,small lpg]	6999	7361
[DK,small petrol]	7721	8217	[PT,medium petrol]	17432	18553	[LV,small petrol]	5824	6198
[DK,medium petrol]	11406	12139	[PT,big petrol]	45664	48600	[LV,medium petrol]	10777	11470
[DK,big petrol]	22233	23663	[PT,small diesel]	11806	12483	[LV,big petrol]	20578	21901
[DK,small diesel]	8999	9495	[PT,medium diesel]	16986	18078	[LV,small diesel]	7102	7476
[DK,medium diesel]	11779	12537	[PT,big diesel]	20995	22345	[LV,medium diesel]	10741	11431
[DK,big diesel]	32786	34893	[PT,lpg]	25296	26906	[LV,big diesel]	18587	19782
[DK,lpg]	13595	14509	[PT,small lpg]	11818	12495	[LV,lpg]	14217	15062
[DK,small lpg]	9043	9540	[SE,small petrol]	9931	10569	[LV,small lpg]	7249	7623
[ES,small petrol]	8473	9018	[SE,medium petrol]	16589	17655	[MT,small petrol]	8389	8928
[ES,medium petrol]	13455	14320	[SE,big petrol]	25680	27331	[MT,medium petrol]	16690	17763

[4] LPG cars are the sum up of "medium" and "big" LPG cars

[Country, vehicle type]	2010	2020	[Country, vehicle type]	2010	2020	[Country, vehicle type]	2010	2020
[ES,big petrol]	31725	33764	[SE,small diesel]	11209	11847	[MT,big petrol]	40790	43413
[ES,small diesel]	9751	10296	[SE,medium diesel]	18180	19349	[MT,small diesel]	9667	10207
[ES,medium diesel]	13549	14420	[SE,big diesel]	28958	30820	[MT,medium diesel]	15121	16093
[ES,big diesel]	27078	28818	[SE,lpg]	21449	22991	[MT,big diesel]	27436	29200
[ES,lpg]	16249	17281	[SE,small lpg]	11680	12319	[MT,lpg]	19954	21239
[ES,small lpg]	9766	10310	[UK,small petrol]	13874	14765	[MT,small lpg]	9763	10303
[FI,small petrol]	7711	8207	[UK,medium petrol]	23922	25460	[PL,small petrol]	5928	6308
[FI,medium petrol]	11540	12282	[UK,big petrol]	44686	47558	[PL,medium petrol]	10968	11673
[FI,big petrol]	22146	23570	[UK,small diesel]	15152	16043	[PL,big petrol]	20944	22290
[FI,small diesel]	8989	9485	[UK,medium diesel]	23209	24700	[PL,small diesel]	7206	7586
[FI,medium diesel]	12763	13583	[UK,big diesel]	39391	41922	[PL,medium diesel]	10932	11634
[FI,big diesel]	24350	25915	[UK,lpg]	29084	31066	[PL,big diesel]	18917	20133
[FI,lpg]	14317	15309	[UK,small lpg]	15355	16246	[PL,lpg]	12772	13545
[FI,small lpg]	9083	9579	[BG,small petrol]	5526	5881	[PL,small lpg]	6803	7183
[FR,small petrol]	10472	11145	[BG,medium petrol]	10225	10882	[RO,small petrol]	5765	6136
[FR,medium petrol]	17312	18425	[BG,big petrol]	19524	20779	[RO,medium petrol]	10668	11354
[FR,big petrol]	39194	41713	[BG,small diesel]	6804	7159	[RO,big petrol]	20371	21681
[FR,small diesel]	11750	12423	[BG,medium diesel]	10191	10846	[RO,small diesel]	7043	7414
[FR,medium diesel]	16964	18054	[BG,big diesel]	17635	18768	[RO,medium diesel]	10633	11316
[FR,big diesel]	30083	32017	[BG,lpg]	12197	12918	[RO,big diesel]	18400	19583
[FR,lpg]	21818	23371	[BG,small lpg]	6900	7256	[RO,lpg]	12372	13113
[FR,small lpg]	12289	12959	[CY,small petrol]	7438	7916	[RO,small lpg]	6565	6936
[GR,small petrol]	7615	8104	[CY,medium petrol]	12322	13114	[SI,small petrol]	5624	5986
[GR,medium petrol]	12615	13426	[CY,big petrol]	23852	25386	[SI,medium petrol]	10407	11076
[GR,big petrol]	24418	25988	[CY,small diesel]	8716	9194	[SI,big petrol]	19872	21150
[GR,small diesel]	0	0	[CY,medium diesel]	10373	11039	[SI,medium diesel]	10373	11039
[GR,medium diesel]	10619	11301	[CY,big diesel]	19499	20753	[SI,big diesel]	17949	19103
[GR,big diesel]	19962	21245	[CY,lpg]	15699	16674	[SI,lpg]	12386	13144
[GR,lpg]	14557	15426	[CY,small lpg]	8792	9271	[SI,small lpg]	6999	7361
[GR,small lpg]	8990	9479	[CZ,small petrol]	5526	5881	[SK,small petrol]	5302	5642
[IE,small petrol]	10660	11345	[CZ,medium petrol]	10225	10882	[SK,medium petrol]	9810	10441
[IE,medium petrol]	17386	18504	[CZ,big petrol]	19524	20779	[SK,big petrol]	18732	19936
[IE,big petrol]	39340	41869	[CZ,small diesel]	6804	7159	[SK,small diesel]	6580	6920
[IE,small diesel]	11938	12623	[CZ,medium diesel]	10191	10846	[SK,medium diesel]	9777	10406
[IE,medium diesel]	16717	17791	[CZ,big diesel]	17635	18768	[SK,big diesel]	16920	18007
[IE,big diesel]	30848	32831	[CZ,lpg]	12160	12894	[SK,lpg]	11626	12298
[IE,lpg]	20683	22102	[CZ,small lpg]	6466	6821	[SK,small lpg]	6676	7017
[IE,small lpg]	12028	12713				[TR,small petrol]	5529	5885
						[TR,medium petrol]	10231	10889
						[TR,big petrol]	19537	20793
						[TR,medium diesel]	10197	10853
						[TR,big diesel]	17646	18781
						[TR,lpg]	11858	12563
						[TR,small lpg]	6529	6885

3.3.2 Fuel costs

The term 'fuel costs' is used to describe costs paid by end users/drivers. This is typically the sum total of fuel resource cost, excise duty, and VAT.In comparison with the Scenarios REF, Scenarios 1 and 2 foresee a reduction in total fuel costs (excluding VAT) of 0.42% and 1.14% respectively (Table 3.g). This translates to reductions of €12.4 and €34.5 billions. Adjusted to include VAT, these values increase to €15.0 in Scenario 1 and €41.2 billion in Scenario 2 (Table 3.g). However, viewed as percentages, the results for both scenarios are essentially identical. Due to the projected increase in the penetration of LPG-powered cars, a reduction in total spending on conventional fuels is anticipated in Scenarios 1 and 2. Spending on LPG is projected to increase accordingly.

Table 3.f Change (% and Meuros) in the accumulated total fuel costs with VAT from 2007 to 2020 compared to the reference scenario

	%		Meuros	
Car type	**Scenario 1**	**Scenario 2**	**Scenario 1**	**Scenario 2**
small petrol (<1.4l)	-2.09	-5.49	-18360.89	-48268.96794
medium petrol (1.4l - 2.0l)	-1.46	-2.42	-13628.67	-22604.34944
big petrol (>2.0l)	-0.98	0.31	-3054.90	964.722688
small diesel (<1.4l)	-0.78	-4.18	-539.01	-2901.766144
medium diesel (1.4l - 2.0l)	-1.00	-3.96	-10050.54	-39903.82182
big diesel (>2.0l)	-0.70	-4.28	-2485.26	-15138.816
lpg (>1.4l)	74.44	195.95	20074.10	52839.80083
small lpg (<1.4l)	83.07	215.96	13014.18	33833.20474
Total	**-0.42**	**-1.14**	**-15030.98**	**-41179.99309**

Table 3.g Change (%) in the accumulated total fuel costs without VAT from 2007 to 2020 compared to the reference scenario

	%		Meuros	
Car type	**Scenario 1**	**Scenario 2**	**Scenario 1**	**Scenario 2**
small petrol (<1.4l)	-2.05	-5.48	-15094.64	-40356.81
medium petrol (1.4l - 2.0l)	-1.44	-2.42	-11259.28	-18984.73
big petrol (>2.0l)	-0.97	0.31	-2552.79	806.14
small diesel (<1.4l)	-0.78	-4.18	-451.75	-2435.19
medium diesel (1.4l - 2.0l)	-0.98	-3.95	-8275.56	-33399.05
big diesel (>2.0l)	-0.70	-4.27	-2066.32	-12689.87
lpg (>1.4l)	74.53	199.15	16575.50	44293.58
small lpg (<1.4l)	83.01	219.40	10705.10	28295.34
Total	**-0.41**	**-1.14**	**-12419.74**	**-34470.57**

The breakdown of these costs into fuel resource costs and excise duties reveals that the majority of the decrease in total fuel costs comes from the reduction in excise duties. The accumulated total fuel excise duties decrease by 0.65% (€10 billions) in Scenario 1 and by 1.76% (€27.5 billions) in Scenario 2, while the accumulated total fuel resource decreases by 0.16% (€2.3 billions) and 0.49% (€7.3 billions) in the scenarios 1 and 2 respectively (Table 3.h and Table 3.i). Increased uptake of LPG therefore has a more substantial impact on total fuel excise duties than on fuel resource costs. This finding reflects the "progressiveness" of fuel excise currently applied to LPG as an automotive fuel in Europe.

Table 3.h Change (%) in the accumulated total fuel resource costs from 2007 to 2020 compared to the reference scenario

	%		Meuros	
Car type	**Scenario 1**	**Scenario 2**	**Scenario 1**	**Scenario 2**
small petrol (<1.4l)	-2.19	-5.40	-7225.57	-17780.34
medium petrol (1.4l - 2.0l)	-1.54	-2.37	-5278.24	-8102.05
big petrol (>2.0l)	-1.00	0.32	-1106.00	349.26
small diesel (<1.4l)	-0.78	-4.19	-248.53	-1335.72
medium diesel (1.4l - 2.0l)	-1.03	-3.97	-4892.16	-18824.00
big diesel (>2.0l)	-0.72	-4.29	-1174.85	-6975.11
lpg (>1.4l)	75.82	198.06	10776.39	28150.69
small lpg (<1.4l)	84.86	216.22	6763.73	17233.34
Total	**-0.16**	**-0.49**	**-2385.23**	**-7283.94**

Table 3.i Change (%) in the accumulated total fuel excise duties from 2007 to 2020 compared to the reference scenario

	%		Meuros	
Car type	**Scenario 1**	**Scenario 2**	**Scenario 1**	**Scenario 2**
small petrol (<1.4l)	-1.93	-5.54	-7869.10	-22576.46
medium petrol (1.4l - 2.0l)	-1.35	-2.47	-5981.08	-10882.68
big petrol (>2.0l)	-0.96	0.30	-1446.79	456.88
small diesel (<1.4l)	-0.77	-4.17	-203.22	-1099.47
medium diesel (1.4l - 2.0l)	-0.91	-3.92	-3383.43	-14575.01
big diesel (>2.0l)	-0.66	-4.25	-891.47	-5714.74
lpg (>1.4l)	72.24	201.08	5799.12	16142.89
small lpg (<1.4l)	80.01	224.55	3941.37	11062.00
Total	**-0.65**	**-1.76**	**-10034.61**	**-27186.58**

3.3.3 External costs due to emissions

Total external costs have been calculated for the five key pollutants/emissions listed in section 3.2 of this study. The increased share for LPG-powered cars penetration can be expected to reduce total external costs during the observed period by 1.30% (€6.6 billion) and 3.72% (€18.8 billion) in Scenarios 1 and 2 respectively. Increases related to the expanded use of LPG are more than compensated for by the decrease of external costs stemming from the use of conventional fuels.

Table 3.j Change (%) in the accumulated external costs from 2007 to 2020 compared to the reference scenario

	%		Meuros	
Car type	**Scenario 1**	**Scenario 2**	**Scenario 1**	**Scenario 2**
small petrol (<1.4l)	-2.22	-5.59	-2209.01	-5571.42
medium petrol (1.4l - 2.0l)	-1.57	-2.50	-1570.31	-2496.54
big petrol (>2.0l)	-1.06	0.34	-323.82	102.26
small diesel (<1.4l)	-0.77	-4.04	-103.90	-542.43
medium diesel (1.4l - 2.0l)	-0.97	-3.82	-1927.50	-7624.90
big diesel (>2.0l)	-0.69	-4.23	-438.79	-2683.24
lpg (>1.4l)	91.71	125.23	0.24	0.33
small lpg (<1.4l)	83.77	163.70	0.22	0.43
Total	**-1.30**	**-3.72**	**-6572.86**	**-18815.52**

A separated calculation based on TREMOVE has been also made for the effect of LPG-powered car penetration on the reduction of *well-to-tank (WTT)* emission of CO2: LPG powered car penetration can be expected to decrease the accumulated external costs of well-to-tank CO2 emission by 1.3% (0.5 billion euros) and by 3.5% (1.5 billion euros) respectively in scenario 1 and scenario 2 for the whole observed period. They correspond to 13 and 35 Mtonnes of reduction of CO2 WTT emission for scenarios 1 and 2 consecutively. Should this reduction in external cost due to WTT emission of CO2 incorporated into the total external cost as figured in the Table 3.j above, the reduction of total external cost during the observed period will be 7.1 billion euros and 20.4 billion euros in scenario 1 and 2 respectively.

3.3.4 Cost efficiency

Assuming that fuel excise duties and taxes are fully returned to the users, the total costs of each of the scenarios have been calculated by the sum of car purchase, fuel resource and external costs.

Penetration of LPG cars in both Scenarios 1 and 2 can be expected to increase the accumulated total cost during the whole observed period by 0.14% (9.9 billion euros) and 0.48% (33.3 billion euros) compared to Scenario REF. These increases are due mainly to the increase in the accumulated total purchase costs as presented in section 3.3.1 with some uncertainties attached to the model's assumption. It can also be assumed that this increase of purchase costs for the new built vehicles (and retrofitted ones) could in reality provide governments with more VAT + tax income + revenue for employees due to the additional gas feeding system (R&D, human resources…). The later effect is beyond the scope of this study.

Table 3.k Change (%) in the accumulated total costs[5] from 2007 to 2020 compared to the reference scenario

	%		Meuros	
Car type	**Scenario 1**	**Scenario 2**	**Scenario 1**	**Scenario 2**
small petrol (<1.4l)	-4.78	-11.26	-61825.77	-145723.99
medium petrol (1.4l - 2.0l)	-3.32	-5.07	-53518.57	-81658.36
big petrol (>2.0l)	-1.98	0.62	-14062.54	4440.82
small diesel (<1.4l)	-1.04	-7.89	-2163.25	-16439.85
medium diesel (1.4l - 2.0l)	-1.72	-8.93	-37556.57	-195421.03
big diesel (>2.0l)	-1.22	-10.23	-10980.17	-92209.14
lpg (>1.4l)	241.57	774.64	120597.68	386716.47
small lpg (<1.4l)	241.98	604.78	69451.46	173581.73
Total	0.14	0.48	9942.27	33286.66

[5] Total sum of Purchase costs, external costs, and fuel resource costs

Figure 4 plots for scenarios 1 and 2, the reduction in CO2 exhaust emissions against the calculated abatement costs per tonne for the year 2010 (green area), 2015 (purple) and 2020 (orange). These are figures calculated for the year 2020. The abatement cost presented in the graph is the sum of changes in vehicle purchase costs and fuel cost (all without tax divided by the change in CO2 exhaust emissions.

At the beginning (2010), the abatement costs are very high: €194/ton CO2 and €264/ton CO2 for reductions of 3.5 Mtonnes and 4.2 Mtonnes respectively for the scenarios 1 and 2. With the time, as the number of LPG cars increases gradually in the stock, the number of reduced Mtonnes of CO2-exhaust is also increasing while in parallel the total cost for fuel is decreasing. The abatement cost is then decreasing in time while the numbers of tonne of CO2 exhaust reduction increases. By 2020 the abatement costs are: €18.6/ton CO2 for the reduction of around 60 Mtonnes CO2 and 2.8€/ton CO2 for the reduction of around 15 Mtonnes CO2, respectively for scenarios 2 and 1.

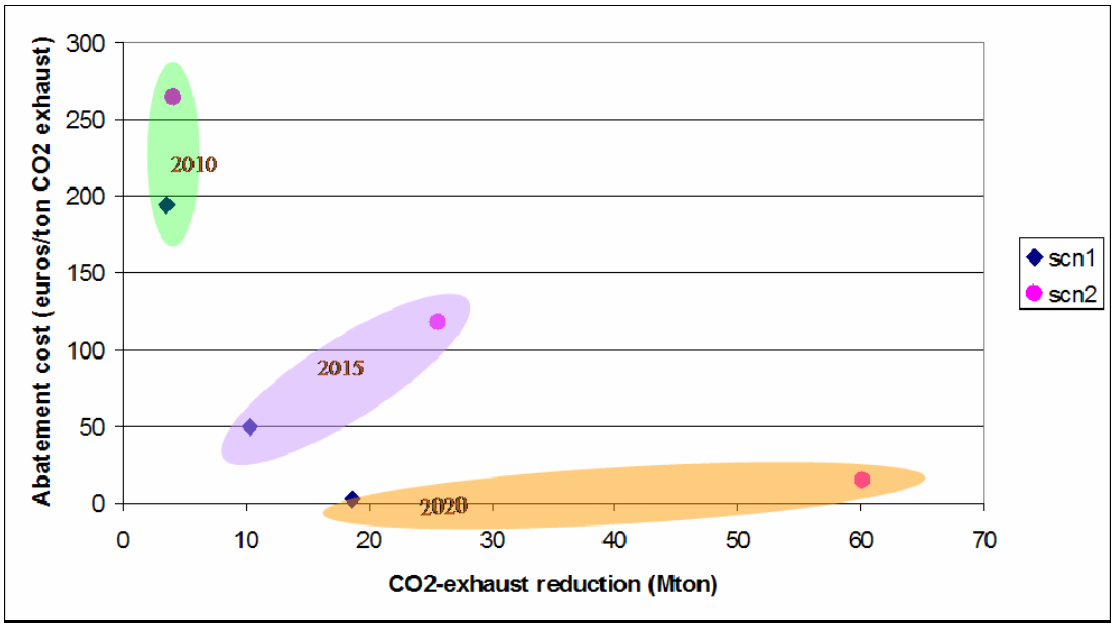

Figure 4 Cost effectiveness 2010, 2015 and 2020

As mentioned at the beginning of this section, more data and additional run should be made with a view to reducing the uncertainties.

4. Conclusions and Recommendations

The use of LPG as an alternative technology for cars can be expected to yield positive impacts regarding fuel consumption and emissions, in both physical and monetary terms.

Table 4.a Share (%) of LPG technologies by 2020

	Scenario		
Variables	**REF**	**1**	**2**
Fleet	3.01	7.65	12.96
fuel consumption	1.78	4.54	10.50
total purchase cost	1.41	5.84	16.93
total fuel cost with VAT	1.22	3.12	7.41
total fuel cost without VAT	1.20	3.06	7.37
total fuel resource cost	1.54	3.94	9.20
total fuel excise duty	0.86	2.17	5.50

Table 4.b Impact of LPG penetrations to the reference scenario on total accumulated costs between 2007and 2020

	%		Meuros	
	Scenario 1	**Scenario 2**	**Scenario 1**	**Scenario 2**
total external costs of all exhaust emissions	-1.30	-3.72	-6572.86	-18815.52
total external cost of WTT CO2 only	-1.26%	-3.54%	-545.06	-1530.05
total purchase costs	0.38	1.18	18900.36	59386.11
total fuel costs with VAT	-0.42	-1.14	-15030.98	-41179.99
total fuel costs without VAT	-0.41	-1.14	-12419.74	-34470.57
total fuel resource costs	-0.16	-0.49	-2385.23	-7283.94
total excise duties	-0.65	-1.76	-10034.61	-27185.58

AEGPL has prepared 3 scenarios: scenario REF has been designed to represent the situation where in the year 2020, the share of total LPG cars in the EU 31 will reach 3%, scenario 2 is considered to be the most optimistic scenario of LPG cars penetration where share of LPG cars will reach more than 12% in the year of 2020, while scenario 1 is considered to be an intermediate scenario. Some key findings based on comparison between the two scenarios REF and 2 can be listed as follows:

- Scenario REF foresee an increase in total fuel consumption from cars to reach 2.13 giga toe in 2020 while total fuel consumption in the scenario 2 will be 0.08% lower than that value
- LPG cars will represent around 1.78% of total fuel consumption in 2020 while in scenario 2 they will represent 10.5% which shows that fuel mix increase more slowly than the share of LPG cars
- Compared to the scenario REF, scenario 2 will reduce in the whole observed period exhaust emissions of CO, CO2, HC, NOX and PM by respectively 2.35%, 3.65%, 2.26%, 2.61%, and 2.46%. In term of mega tonnes, those values are respectively 0.95, 314.8, 0.11, 0.34, and 0.01.
- In term of external cost, the reduction due to scenario 2 compared to scenario REF reach to around 18.8 billion euros (3.72%) in the whole observed period.

- Compared to the scenario REF, scenario 2 will increase, in the whole observed period, the total purchase cost without VAT of cars by 1.18% or 59.4 billion euros "(please see section 3.3.1 on the assumptions taken)".
- During the whole observed period, total fuel cost with and without VAT will decrease by respectively 41.18 billion euros and 34.47 billion euros in scenario 2 in comparison to the scenario REF.
- Decomposing the fuel cost into resource and excise duty, it turns out that the decrease in the later due to LPG car penetration on scenario 2 compared to scenario REF is much more important than the first, i.e. 7.3 billion euros for resource fuel cost and 27.2 billion euros for excise duty. This reveals the progressive nature of the fuel excise duty.
- In the whole observed period, the total cost, calculated as the sum of purchase, fuel resource and external cost, generated by scenario 2 will be 33.3 billion euros (0.48%) higher than that of scenario REF. Most of this cost comes from the purchase cost of cars.
- CO2 exhaust abatement cost due to introduction of LPG cars in scenario 2 will range from 194 euros/ton in 2010 which gradually decreases to 2.8 euros/ton in 2020.

Finally, a small drawback of this study is the fact that no modal choice simulation has been conducted. The share of LPG cars can be obtained by simply modifying the exogenous assumptions of new LPG cars penetration. A study conducted by taking into account the user modal choice based on the variation of user costs and preferences will give a more realistic overview of the future situation.

References

AEGPL[2007] The LPG industry road map

Jeuland, N., Montagne, X. [2004]: EETP "European Emission Test Programme" – Final Report, Institut Français du Pétrole

COWI [2001]. Fiscal Measures to Reduce CO2 Emissions from new Passenger Cars. Final Report to the European Commission, DG Environment.

Friedrich, R., Bickel, P. [2001] Environmental External costs of Transport

TML[2007] TREMOVE: Service contract for the further development and application of the transport and environmental TREMOVE model. Lot 1 (Improvement of the data set and model structure). Final Report.

TNO, IEEP, LAT [2006] Review and analysis of the reduction potential and costs of technical and other measures to reduce CO2 emissions from passenger cars. Final Report to European Commission, DG Enterprise.