Marginal external costs of peak and non peak urban transport in Belgium

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Abstract

This paper discusses intermediate results of an ongoing research project to estimate all external costs from all transport modes in Belgium. It gives estimates of the marginal external costs of air pollution from urban transport. The evaluation of the environmental impacts is based on the European ExternE accounting framework. This methodology uses the impact pathway analysis for the detailed bottom-up assessment of impacts from air pollutants. It integrates state of the art knowledge in the fields of emission modelling, dispersion modelling, dose-response functions and monetary valuation. This paper focuses on the impact of location (rural areas versus cities), regulation, traffic conditions and congestion on environmental externalities. These case studies for Belgium confirm earlier results of the ExternE project that external environmental costs of car transport are significant and that damage to public health is the dominant impact. In addition, it shows that externalities of urban peak traffic are 2 to 4 times higher than for normal urban driving conditions. Finally, it is calculated which occupancy rates are required for urban public transport (trams and diesel buses) to have lower external costs compared to passenger cars.

key-words : *externalities, urban transport, air pollution, congestion, sustainable mobility*

JEL classification : H430, I310 , R490, Q300, Q490

Non Technical Abstract

i) Main issues, questions raised

We know that cars and busses pollute and hence cause damages to historic buildings, public health and ecosystems. How big are these impacts and are they similar for all cars and busses? This paper provides estimates of these damages caused by air pollution from passenger cars and public transport in Belgian cities. These damages include impacts on human health, materials, agriculture, ecosystems and global warming. To this purpose, a detailed methodology is used that quantifies emissions, how they are dispersed and how increased concentrations of pollutants affect man and the environment. These impacts are consequently valued in monetary terms in order to calculate external costs, i.e. costs imposed on nature and society by driving a car. We look which transportation fuels, technologies and transport modes are more harmful to man and the environment.

ii) Structure of the paper

We first describe briefly the methodology used to estimate impacts and damage costs from pollutants. We then discuss how emissions differ between car technologies and fuels. We describe in detail the damage cost from new cars. This paper focuses on the impact of location (rural areas versus cities), regulation, traffic conditions and congestion on environmental externalities. We finally compare private cars and public transport.

iii) Relationship to the existing literature

The methodology used is based on the European ExternE project (1997) in which a large number of multidisciplinary institutes from all European Countries were involved. It is the first time that detailed calculations are made for Belgium. Earlier estimates are confirmed but we add that externalities of urban peak traffic are 2 to 4 times higher than for normal urban driving conditions. We also show which occupancy rates for public transport are required in order for them to be more environmentally friendly then private cars.

iv) Main conclusions and policy implications

The calculations confirm that environmental damage costs of private cars are relatively high and are in the same order of magnitude as private fuel costs. There is however a large difference between cars and locations and e.g. the damages from older diesel cars in congested urban traffic can be up to 4 times as high as for steady rural traffic. Also older diesel busses have high impacts. These data show from a welfare and economic point of view that we need cleaner car technologies and traffic measures in general, and in particular for urban transport.

0. Introduction

If we decide to take our car to cross the city we probably thought about how much time it will take us and what the cost implications are for our personal wallet, but we normally do not take into account the impacts of our journey on public health, the historical buildings in the city centre or on forests 1000 km downwind. These damages to man and the environment are called external costs, as they are not reflected in market prices. This paper deals with estimates of the air pollution costs of different types of passenger cars and public transport. We distinguish different fuels and traffic conditions for 3 types of locations in Belgium (rural, small and big city). The paper focuses to which extent impacts are higher for peak traffic in big cities.

The evaluation of air pollution impacts is based on the accounting framework of the European ExternE project. Earlier estimates for Belgium using ExternE data were based on extrapolation of case studies for neighbouring countries (Mayeres, 1997). Other estimates of transport externalities for Belgium are based on less detailed or on less up-to date methodologies (e.g. Pearce 1996). The figures in this paper are part of a larger research project that further will include estimates of externalities of other environmental impacts as well as accidents and congestion[1]. The results of this exercise can provide the basic data for analysing a myriad of questions related to transport and environmental policies.

The paper describes first the ExternE methodology and defines the cases studied. Second, we discuss the results for the different pollutants. We focus how externalities vary between different technologies, locations and evaluate the impact of congestion on environmental externalities. Finally, public and private car transport are compared in an urban context.

1. The ExternE accounting framework

The evaluation of the environmental impacts will be based on the accounting framework of the European ExternE project. This framework has been developed to account the externalities of electricity generation (1991-1997, EC(1995), EC(1998a)). Since 1996, it has been extented to account for energy related impacts of transport and the results of the first phase were published in 1998 (EC,1998b). The results in this paper are based on this ExternE-1997 accounting framework. In a current project (1998-1999) the methodology is being further developed and applied in several member states of the European Union.

The ExternE accounting framework is based on the ‘impact pathway’ methodology which represents the long way from a ‘burden’ to an ‘impact’ and an external cost (figure 1). Impacts on human health and the environment are quantified in 4 consecutive steps : determination of emission factors, dispersion simulation, impact assessment with dose-response functions, and monetary valuation. This bottom-up approach integrates the state of the art knowledge in different scientific disciplines in a common and coherent framework. We will discuss the methodological issues in more detail in section 3, presentation of results. Detailed information concerning the assessment of the impacts is found in the ExternE reports (EC, 1998a).

The results of the first phase of the ExternE project show that the external costs of private car use are site and technology specific and that urban transport gives rise to much higher externalities than rural transportation. Therefore, we need to consider technology and site specificity in detail.

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[1] “The external costs of transportation “ Study financed by OSTC (See Acknowlegdements). Other partners in this research are K.U.Leuven (accidents) and UFSIA-SESO (congestion).

2. The implementation of the Impact Pathway Methodology

2.1 Reference Technologies and category split

For passenger cars the most representative motor/fuel technologies were identified. As LPG cars only take up a marginal portion of the Belgian car fleet, only diesel an petrol vehicles are retained. According to international and European emission standard legislation, we distinguish between EURO 0, EURO1, EURO 2 and EURO 3 types of vehicles. (see 3.2)

2.2 Calculation of emission factors

2.2.1 Variability of emissions

Accurate quantitative data about actual exhaust emissions for the different pollutants is made a complex issue due to the multitude of parameters involved. A list of the most important parameters is shown in table 1. This list is definitely not exhaustive. Each of these parameters has a significant impact on the quantity and the relative share of each pollutant emitted. Furthermore, it should be noted that several of these are related to each other and cannot be seen as independent variables. In addition, emission factors are evolving rapidly due to regulatory and technological innovation. Therefore emission factors of new and, even more, future generation vehicles can differ substantially from emissions of the present day fleet but carry a higher degree of uncertainty due to possible changes in regulatory standards, the unavailability of measurements and unknown technical advance.

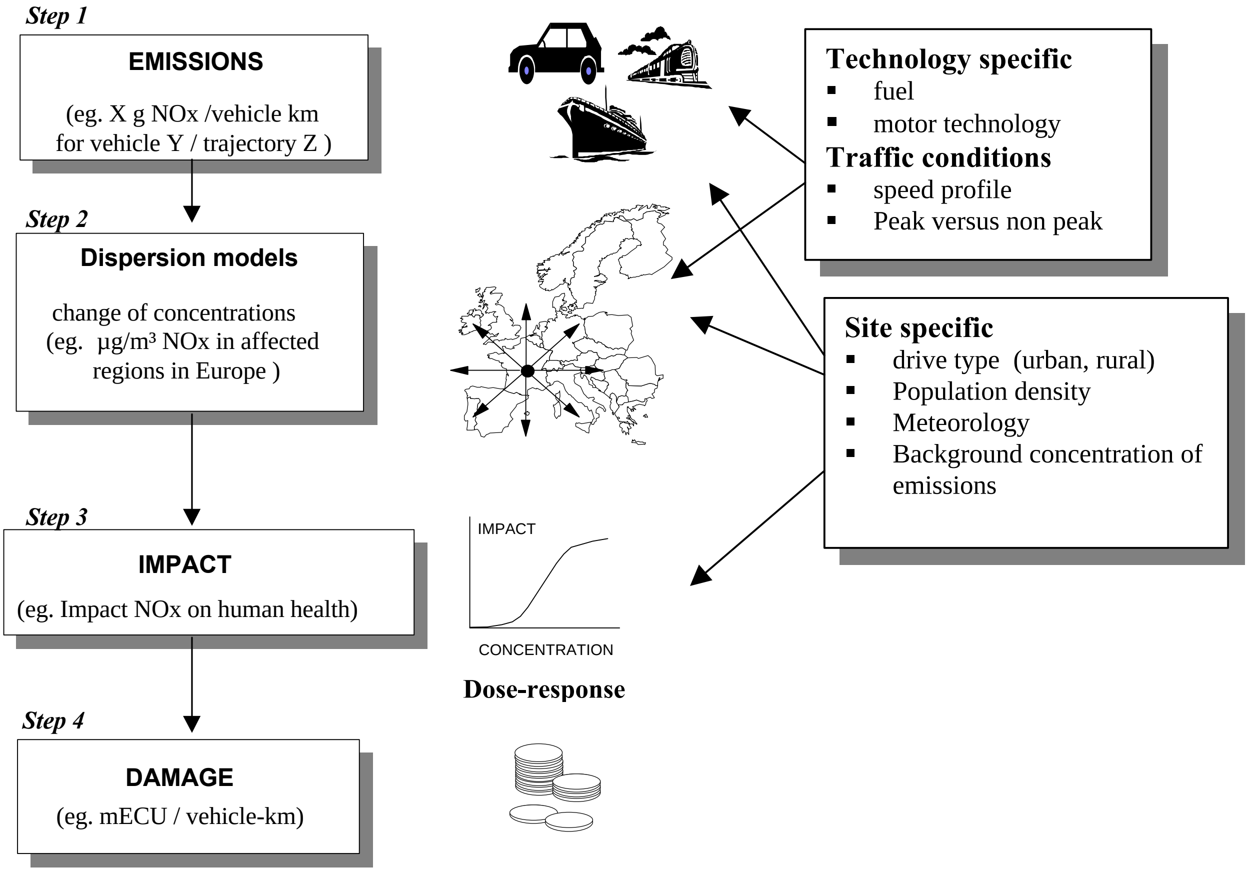

Figure 1 : the impact pathway methodology

2.2.2 Assessment of emission factor models and calculation of emission factors

In Europe, a number of national or European research projects are devoted to the determination of emission factors of road transport vehicles. A common feature is that they are based on (extensive) laboratory measurement campaigns. All models attempt to incorporate some of the parameters described above to account for the variability of emission factors. Generally, the models can be divided in 2 main categories :

1. Models based on average speed emission factors. The most important model of this group is the COPERT model (Egglestone, 1993). The most recent version is based on COST319 and MEET ('Methodologies for estimating air pollutant emissions from transport'). The latter is a recent European research project of different European labs which builds further on the same methodology experience.

2. More complex models are based on emission matrices, i.e. emissions as a function of instantaneous speed and acceleration**.** The Swiss-German 'The Handbook of Emission Factors' (BUWAL/INFRAS, 1995) belongs to this category.

Table 1: Parameters influencing emission factors

Parameter	**categories**	**covered in the data set?**
1. technology and vehicle related		
Type	passenger car/ motor cycle/ bus/ van / truck / puller	yes
motor/fuel technology	diesel/ petrol/ LPG/ CNG/ H2/ hybrid/ electric/ fuel cell….	diesel +petrol
emission control technology	EURO 0, 1, 2, 3,…	yes
cylinder capacity	<1.4 L / >1.4, < 2.0L / >2.0L	yes
Weight		not explicitly
Manufacturing year		not explicitly
2. operational circumstances		
speed profile/ road type	urban/rural/highway	yes
traffic density	peak/non peak	yes
motor condition	cold start/hot	yes
mileage/ ageing	number of km. driven	only TWC cars (3-way catalyst)
altitude/ambient temperature/ loading/ road gradient		fixed
driving behaviour	normal/aggressive	no
emission control break-down		no
Maintenance		no
…		

For this paper, emissions are calculated by means of the HBEFA-model because it allows to calculate the impact of congestion. For the assessment of marginal external costs we need to take into account detailed information including location (e.g. road type), traffic conditions , vehicle type and mileage. In this respect the HBEFA model shows clear advantages as it incorporates both a large number of traffic situations and the effect of mileage (for TWC cars). COPERT/MEET is inherently less suitable as it is mainly applied for medium and large scale applications (eg. national emission inventories). Hence, the effect of speed variability, in particular in peak traffic situations of less than 20 km/h, is underestimated by COPERT/MEET.

We identified 3 drive types for passenger cars - ‘urban drive’, ‘highway’ and ‘rural drive’ – and for each we distinguish between peak and non-peak traffic conditions. For the urban and highway drive the peak traffic condition should be regarded as ‘congestion’ (average speed of 5 and 10km/h respectively), while the peak rural drive is merely increased traffic density. In total, we distinguished between 7 traffic condtions, 3 different cylinder capacity ranges and 4 different mileages. An overview of the parameters taken into account is given in the last column of table 2. In this paper, we only deal with the most important ones. We do not discuss cold start, although it leads to an important increase in emissions. We neither look at cylinder capacity or mileage, results in this paper refer to a cylinder capacity of 1.4-2.0L and an average mileage of 60.000km.

It should be kept in mind that a certain degree of uncertainty will remain due to the difficulties inherent in accurately predicting vehicle usage in real-world driving conditions and to the global character of emission models (many different vehicles covered by one class in the emission factor table). Several studies performed by VITO (De Vlieger, 1996) indicate that real world emissions, measured on the road with the so-called VOEM-system, can differ substantially from the average emission estimates based on the available models.

2.3 The evaluation of location specificity

Earlier results have shown that environmental externalities from transport are very site specific. Therefore the study will result in a tool that allows to calculate the impacts of specific road trajectories. For the dispersion of emissions (step 2 in figure 1), the tool includes two types of models for respectively the local (up to 50 km from the source) and regional (Europe wide) scale. Whereas the European models use large grids (50 x 50 km), the local dispersion is based on very small gridcells, especially close to the road.

In this paper, we want to explore the relative importance of location by means of a simplified world model (SWM) which allows to evalute the combined influence of dispersion of pollutants and population density. For the estimation of impacts on the local scale (up to 50 km), we have defined 3 locations in the simplified world model: namely ’rural or country average’, small city, and large city, each of them being reasonably representative for a typical Belgian geographical situation. The model simplifies the world in the sense that it assumes an evenly distribution of population within certain big blocks. (table 2).

Table 2 :typical locations in Belgium

<table>
<tr><th></th><th colspan="4">population density distribution (inh/km²) and dispersion parameters</th></tr>
<tr><td></td><td colspan="4">distance to emission source</td></tr>
<tr><td></td><td>less than 2 km</td><td colspan="2">from 2 to 10km</td><td>from 10 to 50 km</td></tr>
<tr><td>rural
= country average</td><td>350
rural</td><td colspan="2">350
rural</td><td>350
rural</td></tr>
<tr><td>small city
(80.000 inh.)</td><td>5000
urban</td><td colspan="2">350
rural</td><td>350
rural</td></tr>
<tr><td>big city
(1.000.000 inh.)</td><td>15000
urban</td><td>4700
urban
(<6.5 km)</td><td>350
rural
(>6.5 km)</td><td>350
rural</td></tr>
</table>

Belgium has a relatively high population density of 326 inhabitants per km^2 and it has many urbanised areas, smaller towns and cities, with only a few major agglomerations. Consequently, the ‘rural’ case for Belgium is still characterised with high population densities, compared e.g. to case studies for France. Because of the importance of traffic in the more populated areas in the country, the case ‘country average‘ is chosen as the reference case, as it is more representative than a ‘rural area' location (e.g. in the Ardennes) would be. The 'big city' case is based on a simplification of population and geographical data for Brussels. The dispersion modelling also takes into account the differences between rural and urban areas related to dispersion parameters and to meteorological data - in particular lower ground level wind speeds in urban areas.

2.4 The definition of location specific traffic conditions

In a next step, the locations are related to drive types which can be regarded as representative or typical for a traffic situation in that area. The 10 combinations of drive types with locations (called 'cases') which are studied in this paper, are depicted in table 3. Because emphasis is on urban transport, the drive types rural and highway peak are not considered here. The case 'large city ring', was added to include highway traffic at the outskirts of a large city. In this way, the 10 cases represent a major part of all vehicle-kilometer produced, as well as some typical high exposure situations. In further discussions, the case 'rural normal-country average' will be referred to as the reference case for comparison.

Table 3 : combinations of drive types and locations

	location			
	country average	**small city**	**big city**	**big city ring**
drive type				
Rural normal	**(ref.)**			
Urban normal				
Urban peak				
Highway normal				
Highway peak				
Rural peak				

3. Discussion of results

First, we will discuss the results for the reference case and then we will see how different factors (legislation, location, congestion) have an impact on total externalities.

3.1 External costs of a present-day EURO 2 car in the reference case

3.1.1 Overview

Table 4 shows the results by pollutant for the current diesel and petrol cars. Although it is the objective of the study to consider all priority impacts from all relevant burdens, these results of the first phase only include impacts from airborne pollutants. The list of energy-related pollutants can be subdivided in 3 categories, namely 'classical pollutants' (CO, NMVOC, NO_x, PM2.5, SO_2), greenhouse gasses (CO_2, CH_4 and N_2O) and carcinogens (benzene, 1,3 butadiene, diesel particles). It has to be noted that some potentially harmful pollutants were not included in the analysis due to insufficient emission factor data or because no established dose-response functions or monetary valuation is available. The latter is the case for NH_3, Pb, benzo-a-pyrene, formaldahyde and ethene.

Table 4 : external costs of a present-day EURO 2 in the reference case

		external cost reference case (mECU/vkm[2])	
pollutant	**impact scale**	**petrol EURO 2**	**diesel EURO 2**
CO	local	7.88E-04	4.54E-04
carcinogens	local + regional	1.71E-02	2.40E-01
SO_2	local	6.51E-02	7.36E-02
	regional	1.92E-02	2.17E-02
	sulphates (reg)	2.95E-01	3.33E-01
PM2.5	local	5.00E-01	10.96 E+00
	regional	9.04E-02	1.98E+00
NO_x	**ozone (**reg)	4.81E-01	5.87E-01
	nitrates (reg.)	3.23E+00	3.94E+00
ecological impacts	regional	Nm	Nm
global warming	global	5.04E+00	3.41E+00
NH_3, Pb, benzo-a-pyrene, ethene, formaldehyde		Not considered	
Subtotal		**9.73**	**21.54**

local = up to 50 km, regional = + 50 km from the emission source.
nm = not monetised.

3.1.2 The importance of public health damages for traditional pollutants

For the classical and carcinogetic pollutants, the ExternE project has established dose-response functions from literature for human health, agriculture, materials and ecosystems. These were used to calculate physical impacts (e.g. increased number of morbidity cases, loss of agricultural productivity) due to increases in concentrations. (step 3 in figure 1). Finally, these impacts were valued in monetary terms. If possible, these are based on market prices. If not, they are based on literature studies that try to estimate the “willingness to pay” from individuals to enjoy the benefits of certain goods and services or to avoid certain impacts.

Among the monetised impacts, the impacts on human health are the most important category, and especially the impact on chronic mortality. This reflects the growing consensus about the important impacts from fine particulates, including nitrate and sulphate aerosols formed following the emissions of NO_x and SO_2. For these health impacts, the dose-response functions do not apply a treshold because even for very low concentrations, groups in society are affected. Therefore, we calculate large impacts from very low increases in concentrations if they affect large groups. e.g. emissions in the centre of a big city. The monetary valuation of mortality not only takes into account the loss of income but in additon the value people attach to a reduced mortality risk. Second, the valuation takes into account the estimated number of years lost. Based on an average from a wide range of studies using different methodologies, the impact on mortality is valued at 84 KECU per year of life lost.

Compared to the impacts on public health, the damages to crops and materials are much less important. Impacts on buildings and materials only contribute marginally to the total damage for SO_2 or particulates. Only for ozone agricultural impacts contribute to about 25 % of the total damage. The impacts of acidification on ecosystems can be quantified in terms of changes in the N° of ha for which critical loads are passed. As it is however not possible to value this impact in monetary terms it cannot be included in table 4 and will not further be discussed.

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[2] mECU = milli ECU = 0.04 BEF

The impacts from global warming have been estimated following specific models[3]. The evaluation of different scenarios and assumptions showed that one single number does not really reflect the uncertainties involved in global warming issues. Therefore, the best estimate is a range from 18 to 46 ECU per ton of CO_2, and a wider range of 3.9 to 139 ECU per ton of CO_2. However, as this paper does not focus on global warming issues, an average of 32 ECU per ton of CO_2 was used for ease of presentation and interpretation.

3.1.3 Comparison of the subtotals for diesel and petrol

Table 4 shows that for modern petrol cars, global warming is the most important impact, followed by NO_x. Damages from NO_x are especially due to the long range impacts from nitrates. Because it takes time to form nitrates, they are only relevant for the regional scale (> 50 km). The same argument goes for sulfates and consequently the regional impacts are more important than the local ones for both NO_x and SO_2. The estimate for ozone is less important but this is only a very rough guess. Because difficulties in modelling ozone formation, we are not (yet) able to calculate site specific impacts and the results in table 4 are based on a European average. This remark also affects the ozone impacts of NMVOC.
Even for petrol cars, table 4 suggest that externalities from particulates are not negligible. However, present-day knowledge of particle emissions of petrol cars (amount, particle size, composition, health impact) is quite limited and should be regarded as less reliable. In this respect, further research on particle characteristics and health impacts, in particular for petrol cars, seems prerequisite.

For modern diesel cars, local impact of particulates is by far the most important impact category, and amounts to 13 mecu/vkm. Impacts from NO_x are a little bit higher than from petrol cars but for global warming diesel performs better. In total, externalities for diesel cars are about twice as high than for petrol cars.

The results presented in table 4 are perfectly in line with other case studies carried out in the previous phase of the ExternE project (EC 1998b).

3.1.4 Uncertainty of the results and comparison of cases.

The impact pathway methodology only integrates our best understandings in the different related disciplines. Consequently, it also cumulates the uncertainties in all the data and models used so that the overall results are subject to relatively large uncertainties, which are quantified and discussed in the detailed reports. As an overall indicator, we estimate that the statistical uncertainties can be characterised by a lognormal distribution with a geometric standard deviation (σ_g) between 4 tot 6 for most impacts. This implies that the 68 % interval is determined by dividing and multiplying the best estimate with 4 to 6. In addition, other types of uncertainties like those related to ethical choices or applicability of dosis-response functions can best be handled with sensitivity analysis. These uncertainties should especially be taken into account when discussing the absolute figure of externalities, or comparing very different types of pollutants or impacts. When it comes to comparing the influence of factors like congestion or location, they are less important.

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[3] FUND model from IES, Amsterdam and Open Framework Model. More details can be find in : European Commission, DGXII, Science, Research and Development, JOULE (1998b). ‘ExternE’ Project. Analysis of Global Warming Externalities. To be published by the EC.

3.2 Impact of regulatory emission standards on external costs

As the life expectancy of a car is around 10 years, we also have to consider older cars. As emission standard regulation allowed higher emissions we may expect higher external costs. Figure 2 shows the external costs of the past and future regulation of emission standards, at least for the 'regulated pollutants'. The figures refer to the reference case 'rural non peak' We need to consider 4 categories EURO 0, 1, 2 and 3 which are documented in table 5. In addition, the figures also reflect technological changes over time that were not subject to regulation as well as the impacts of changes in the fuels. This is important for the reduction of sulphur content of diesel, which affects SO_2 emissions. The introduction of lead free petrol which reduces emissions of lead but increases the emissions of benzene, is not reflected in the analysis as petrol cars are supposed to use lead free petrol.

Table 5 : category split of the Belgian car fleet

	Passenger cars		Buses > 8 passengers & Trucks > 3,5 tons	
category	Legislation	Mandatory introduction date	Legislation	Mandatory introduction date
EURO 0	ECE 15/00-15/04 (EEC 83/351/EEC)	N/A	88/77/EEC	N/A
EURO 1	91/441/EEC 88/76/EEC (>2000 cc)	1/1/93 1/1/90 (>2000 cc)	91/542/EEC - Step A	1/10/93
EURO 2	94/12/EC	1/1/97	91/542/EEC - Step B	1/10/96
EURO 3	Draft Directive	1/1/2001	Under preparation	2001 or later

The categories EURO 0, 1, 2 and 3 are used both for petrol and diesel cars, since European legislation 91/441/EC and 94/12/EC applies for both engine technologies and exhaust limit values (for CO, NMVOC and NO_x) in the legislation are the same for both technologies. Figure 2 clearly shows the large benefits from the introduction of the three-way catalyst for petrol cars (change of EURO 0 to EURO 1), especially for NO_x emissions.[4] It further shows that the benefits from consecutive legislations EURO 2 and 3 are much less important. We need however to take into account that - as the figures do not include cold start emissions - they neither show the benefits from the EURO 3 regulation to include a cold test drive cycle.

For diesel cars, the picture is different, because NO_x emissions were already conform to the standards for older cars. Note that for modern cars (Euro 2) NO_x emissions for diesel are relatively higher. Until now, the most important pollutant, particulates, has not been regulated. Future 'EURO 3' diesel cars however – which are considered to be in compliance with the envisaged control technologies of the AUTO-OIL programma - includes PM emission standards. Consequently, EURO 3 legislation will result in an important reduction of externalities for diesel cars.

Both for petrol and diesel, CO_2 emissions are not subject to this legislation, and figure 2 shows that autonomous technological progress has not resulted significantly in a reduction of these externalities in recent years. As other externalities are being reduced, the relative importance of CO_2 is increasing.

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[4] Note that intermediate technologies such as 'improved conventional' and 'open loop TWC' (those technologies that where developed in ordert to comply with Directive 88/76/EEC for < 2000 cc) are not applicable for Belgium.

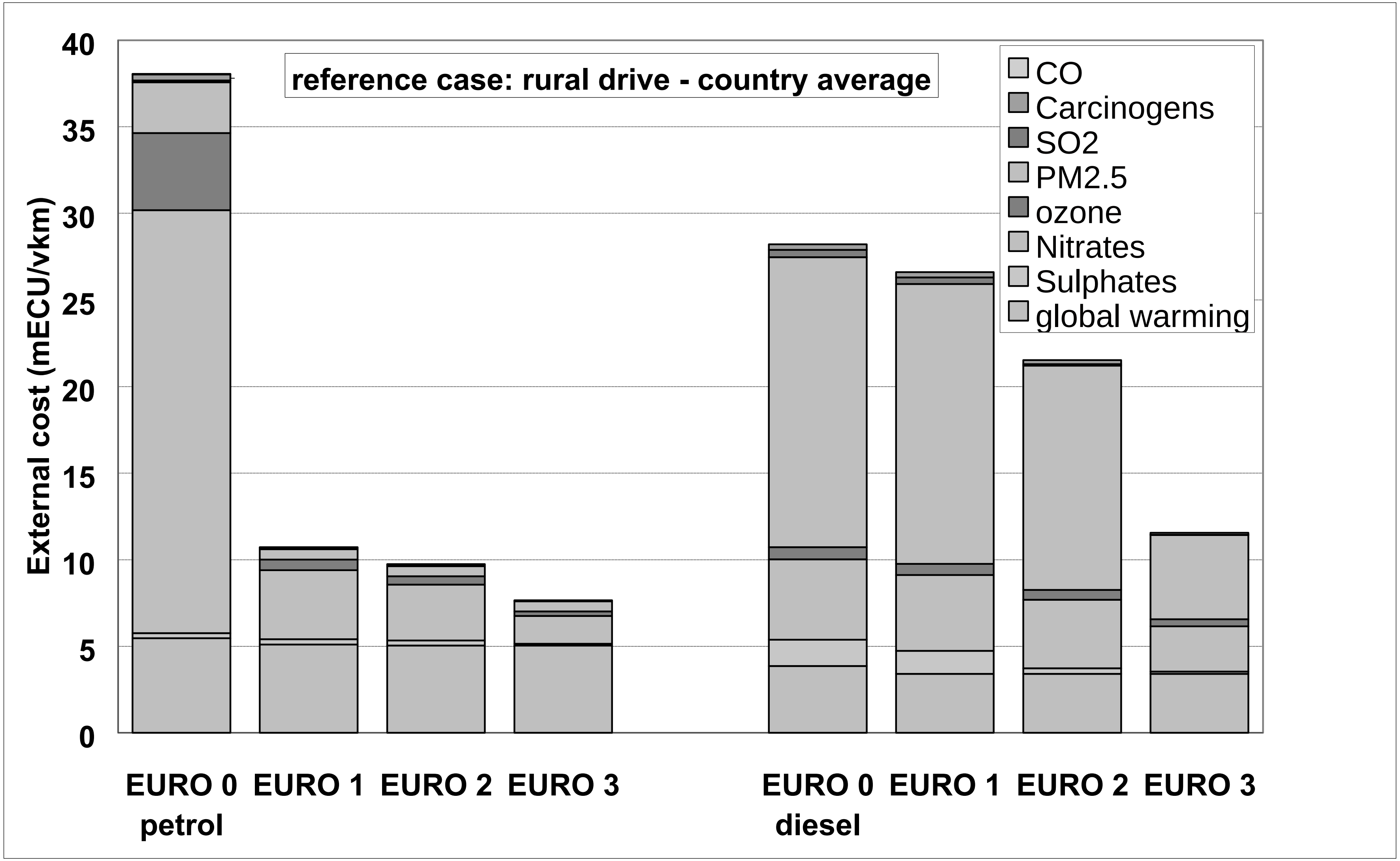

Figure 2 : impact of emission standard regulation on external costs

Overall, figure 2 shows the importance to take the composition of the car park into account, especially for older petrol cars for which external costs amount to 38 mECU/vkm. Whereas the old EURO 0 petrol cars have higher external costs than old diesel cars, the opposite is true for both present and future cars.

3.3 Impact of location on external costs

A further step in the analysis concerns the (combined) influence of higher population densities and increased emissions of less favourable cases with respect to the reference ‘rural – non peak’. Figure 3 and Figure 4 depict external costs estimates for a present-day EURO 2 petrol and diesel passenger car in the earlier described non peak cases.

External cost estimates show a sharp increase from approx. 10 mECU/vkm for the reference case to 19 mECU/vkm for the big city in the case of petrol cars and from 20 to 100mECU/vkm for diesel cars respectively. These changes are the results from changes in the emissions because of differences in traffic conditions between rural and urban traffic and from higher local impacts per kg pollutant of PM2.5, SO_2 and carcinogens for emissions in the city.

The differences in emissions are especially important for petrol cars. Different traffic conditions lead to higher CO_2 emissions for urban traffic compared to rural traffic and the big city ring. Because higher speed leads to higher NO_x emissions, the latter are significantly higher for the ringway.

The impact of higher population densities is especially important for particulates and for the increase between small and big city. For the big city, PM2.5 reveals itself as the dominant pollutant, even for petrol cars. For diesel cars, the externalities in the big city are 5 times higher compared to the reference case. A more detailed subdivision of the local impacts show that in particular the immediate vicinity of the road (first 2 km) is responsible for external cost increases. This can be explained by the very nature of (urban) traffic emissions, namely at ground level in highly populated areas.

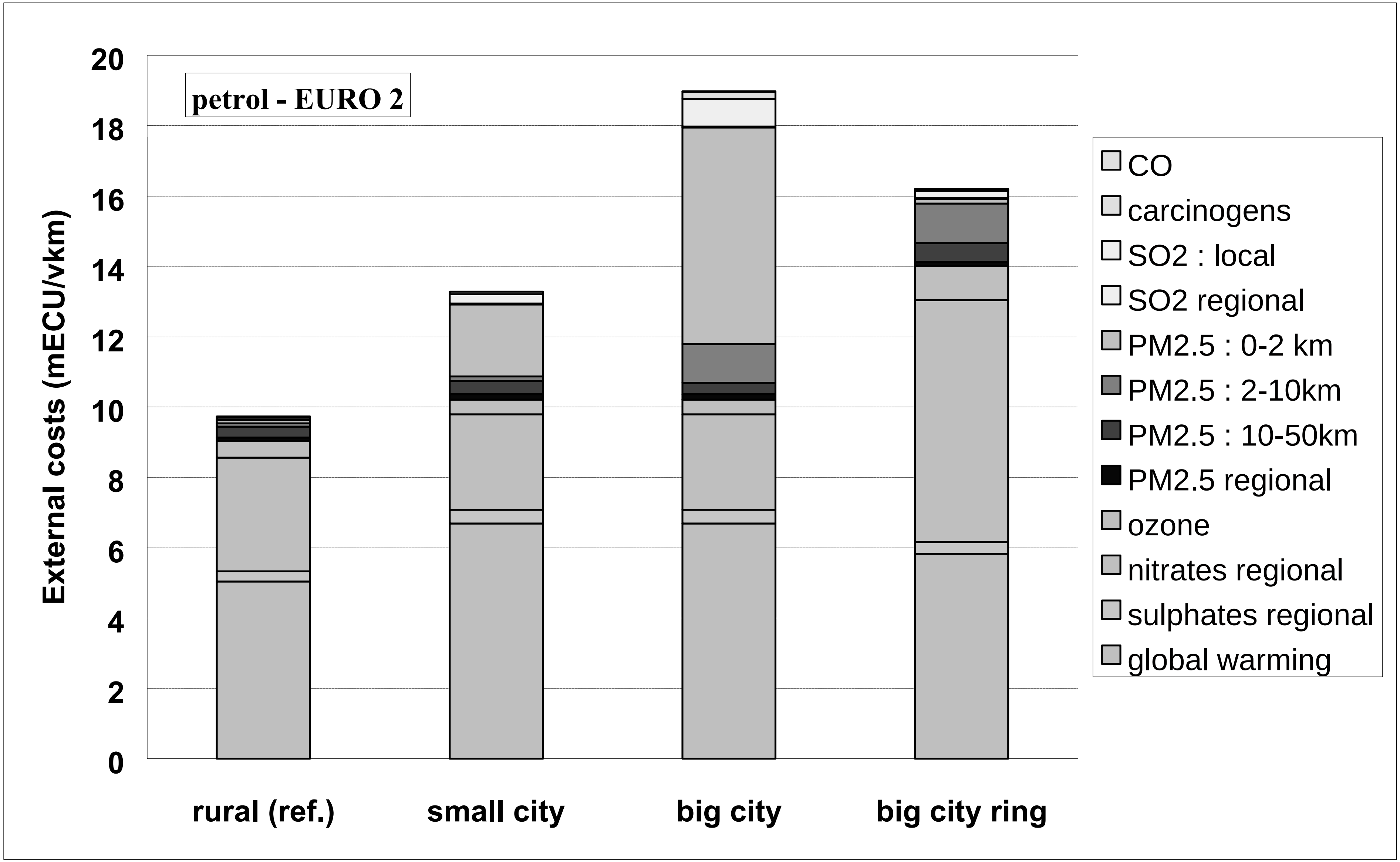

Figure 3 : external costs of different non peak cases for a EURO 2 petrol car

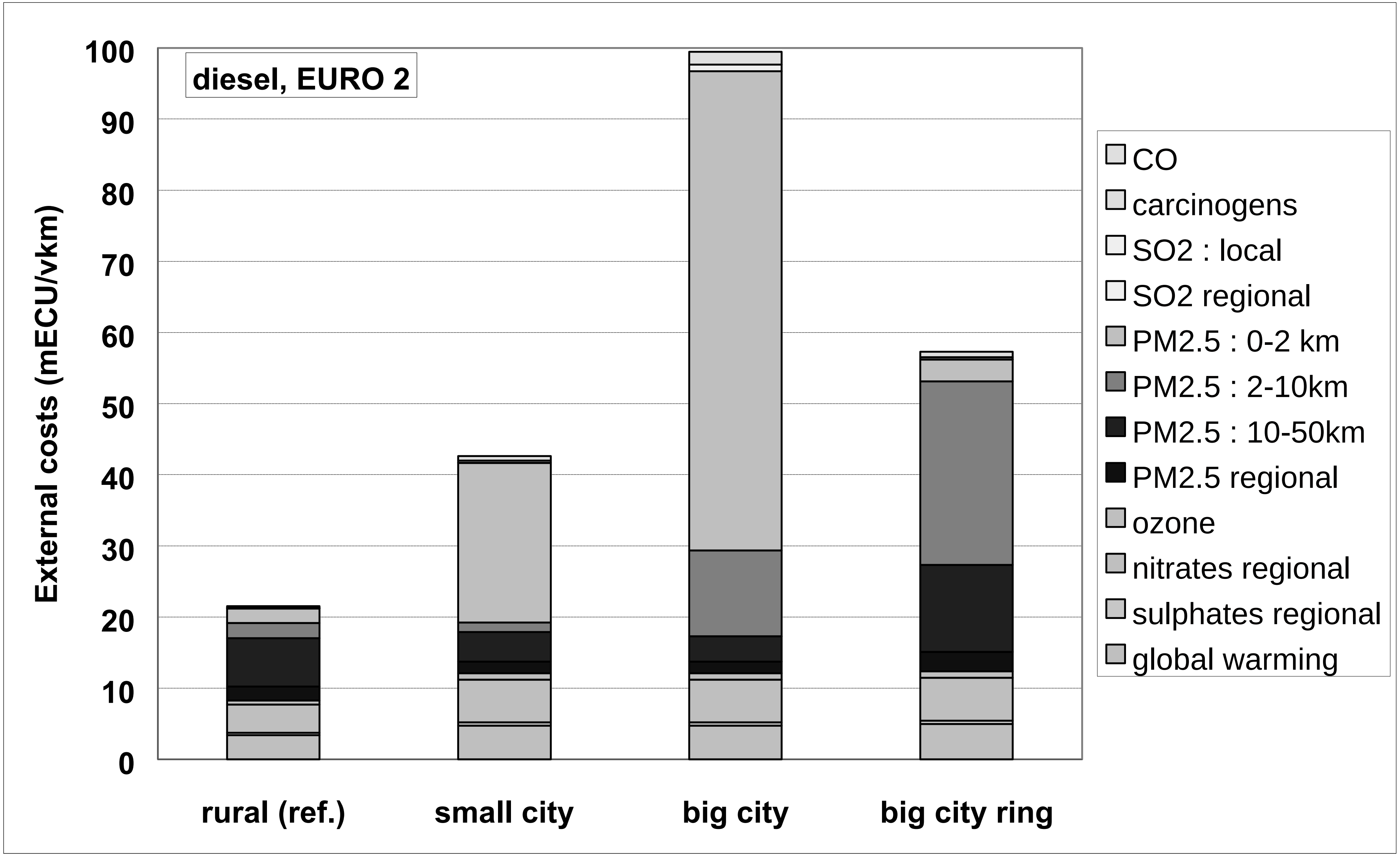

Figure 4 : external costs of different non peak cases for a EURO 2 diesel car

The differences between the ‘big city ring’ and other cases are more difficult to explain. Both for petrol and diesel, the total is between small and big city but the explanation is different. For petrol cars, the (long range) impacts of the higher NO_x emissions become the dominant impact category and compensate for lower CO_2 emissions and lower PM impacts near the road. Because the big city is about 10 km away, the PM impacts in the 2-10 km and 10-50 km range increase. This is especially important for diesel vehicles, although externalities of the big city ring traffic are only half of those from the centre of the city, they are twice as high as the reference case. These figures clearly show that this type of traffic needs to be distinguished from urban traffic, but may not be overlooked for the evaluation of air quality in the city centre.

3.4 Impact of peak traffic on external costs

In this section, the influence of peak traffic (also called congested or stop&go traffic) is considered. For this reason, 3 different drives are selected, i.e. a urban peak drive at 5km/h, a normal urban drive of 28 km/h and a ‘free flow’ drive (similar to the rural drive of 60km/h). In Figure 5 and Figure 6, external costs estimates are produced as a function of average speed by fitting the 3 selected drive types into one curve. In addition, different combinations of locations and technologies were chosen as a parameter.

A general and major perception of this figures is the relatively flat curve for higher average speeds, including both free flow and urban non peak drive types. On the other hand, peak traffic is characterised by very high values. For petrol cars peak values are a factor 2 to 3 higher than ‘free flow’ externalities for a small city and a factor 3 to 4 for a big city, with the higher ranges for the most recent vehicle types. For diesel cars these factors go from 3.5 for a EURO 0, to 2.5 for the other types (both for small and big city). Petrol EURO 3 cars are not included in the figure as results approximately coïncide with the EURO 2 standard. These results indicate that the impact of congestion on air pollution externalities is higher than estimated in earlier studies for Belgium (Mayeres, 1997) or the US (Litman, 1995). This is primarily due to the fact that, in comparison with these studies, the chosen emission factor model takes into account the effect of speed variations of peak traffic in a more effective way.

It should be noted that these studies analysed ‘traffic during peak hours’, which could be a mix of different traffic conditions, whereas in this study the case explicitly investigates the marginal external costs of an additional car in congested traffic.

It is concluded that peak traffic should be regarded as a predominant factor in external costs resulting from air pollution. In combination with unfavourable geographical conditions and older motor technology, external cost estimates can mount upto extremely high values as more than 180mECU/vkm for petrol cars and 500mECU/vkm for diesel cars.

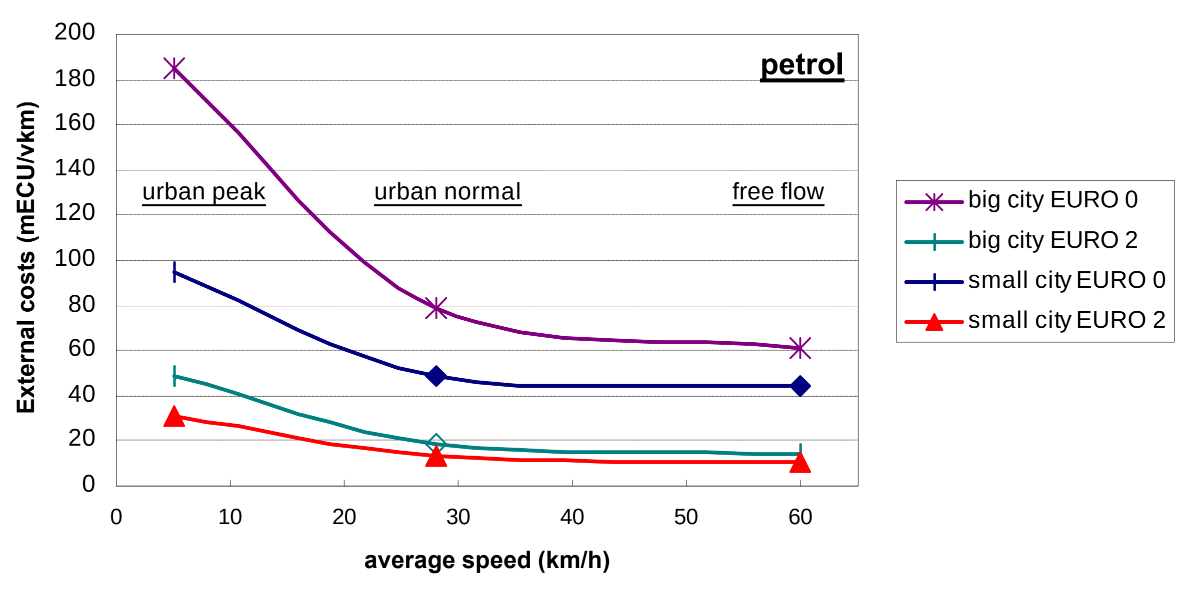

Figure 5 : speed variability of external costs for petrol cars

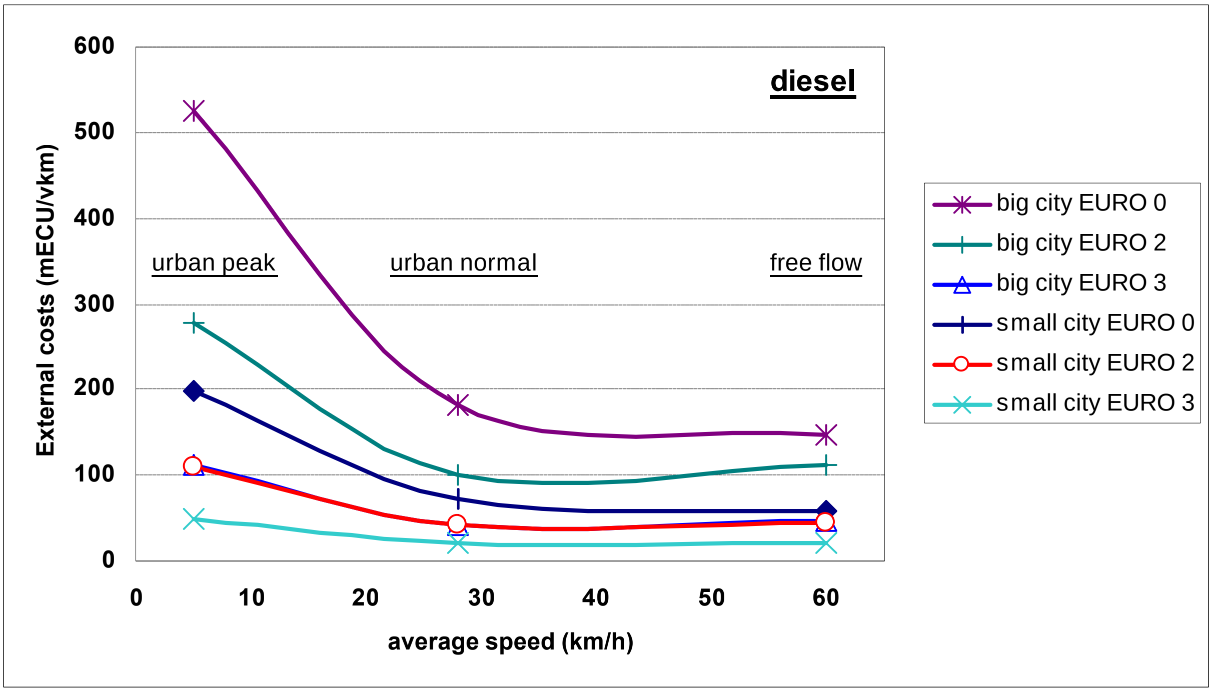

Figure 6 : speed dependency of external costs for diesel cars

3.5 External costs of public transport

For urban transport, it is interesting to compare passenger car results with those of public transport. In this paper only diesel buses and present-day trams are considered in detail. The remainder of the analysis and results are limited to the case ‘urban normal drive’ in a big city, which is one of the most common driving situations for buses.

For trams, estimates are based on average figures for electricity production in Belgium (De Nocker, 1998). The external costs of power generation have been estimated with the ExternE methodology (EC, 1998c). Although the impacts of power plants do differ from transport, a consistent comparison is possible. For power plants using fossil fuels, the methodology is almost identical. The main difference between emissions from power plants and cars is that the former are emitted from high chimneys. Consequently, local concentrations and impacts are much lower. As local impacts dominate for particulates, the total impact per kg $PM_{2.5}$ is 5 to 40 times smaller for power plants. Because the major impact from NO_x and SO_2 emissions is the regional impact from nitrate en sulphate aerosols, the total impacts per kg pollutant are very close. Second, for global warming, impacts from emissions from power plants and transport are identical per ton CO_2-equivalent. The impacts from nuclear on the contrary are very different and different types of uncertainty do apply. Compared to fossil fuel cycles, the best estimates for externalities from nuclear (around 4 mECU/kWh) are much lower than those for gas (16 mECU/kWh) and especially for coal power stations without flue gas desulpherisation (136 mECU/kWh) [5]. Consequently, although 60 % of the electricity is produced with nuclear energy, the coal fired power stations account for more than 85 % of the average external costs of 41 mECU/kWh. Combining tram energy consumption with external costs of the Belgian electricity mix leads to an external cost estimate for trams of 160 mECU/vkm. As coal fired power stations will introduce more flue gass cleaning or will be replaced by gas fired stations, future impacts are likely to decline.

For buses, only diesel technology is included, as it takes up the major part of present-day bus fleet. Figure 7 shows the external costs for buses for 4 vehicle categories. These categories have been explained in table 5. For buses, the same EC legislation applies as for heavy-duty trucks. This legislation is a different one than for passenger cars, because for heavy duty vehicles (> 3,5 ton), the approval is done on a stand-alone engine and not on the complete vehicle, but a similar division of EURO 0 upto EURO 3 with approximately the same introduction dates can be made (see table 5). For diesel buses, the external costs per vkm vary from 1964 mECU/vkm for EURO 0 buses to 744 mECU/vkm for present-day buses and 528 mECU/vkm for future EURO 3 buses. These figures apply for the case ‘big city- urban normal drive’. This positive trend is due to a decrease in particulate emisions and, to a lesser extent, lower NO_x emissions. As particulate emissions are responsible for a major portion of the externalities, it is expected that the introduction of alternative fuel buses (CNG, LPG) would lead to significantly lower results. This will further be evaluated in the project.

It is noted that trams (with a similar capacity as buses) have much lower externalities due to the the lower local impacts as emissions from (fossil) electricity production take place from high chimneys in remote areas and nuclear electricity production has lower externalities.

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[5] For reasons of consistency, these figures are based on an external costs for global warming of 32 ECU/ton C02-equivalent.

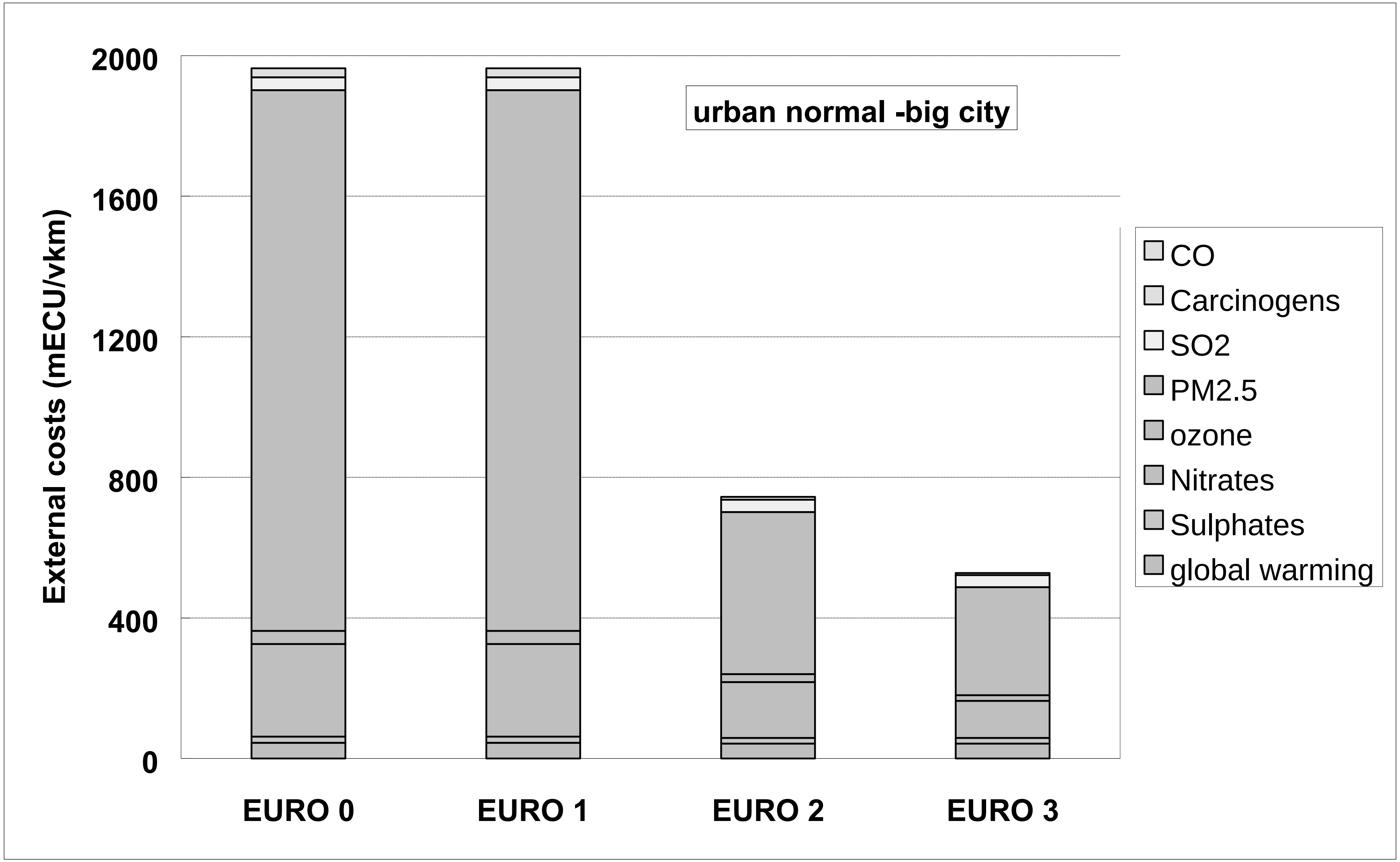

Figure 7 : impact of emission standard regulation on external costs of diesel buses

3.6 Comparing passenger cars and public transport

In order to compare different transport technologies and transport modes, external costs for public transport should be expressed in terms passenger-kilometer instead of vehicle-kilometer. Consequently, as shown in Figure 8, seat occupancy rates are a predominant factor of public transport externalities. Note that the Y-axis has a logarithmic scaling. The straight lines indicate fixed external costs of different passenger car technologies, with an average occupancy of 1.3 person per car. It can be seen that present-day EURO2 buses perform better with respect to recent diesel cars if the occupancy rate is more than 15%. In order to have lower externalities than recent petrol cars, occupancy rates should at least be 50%. On the other hand, a EURO 2 bus on maximum capacity does have quite low externalities. For older diesel busses however externalities per passenger km remain relatively high. Especially in big cities, they are likely to have higher impacts compared to modern gasoline cars.

As shown before, trams perform very well in an urban context with respect to the other vehicle technologies. A similar comparison in a urban peak situation would lead to approximately the same conclusions, as emissions for bus and car increase with the same factor with respect to urban non peak driving. As occupancy rates of public transport are usually quite high during peak hours, modern buses should perform quite well in peak periods.

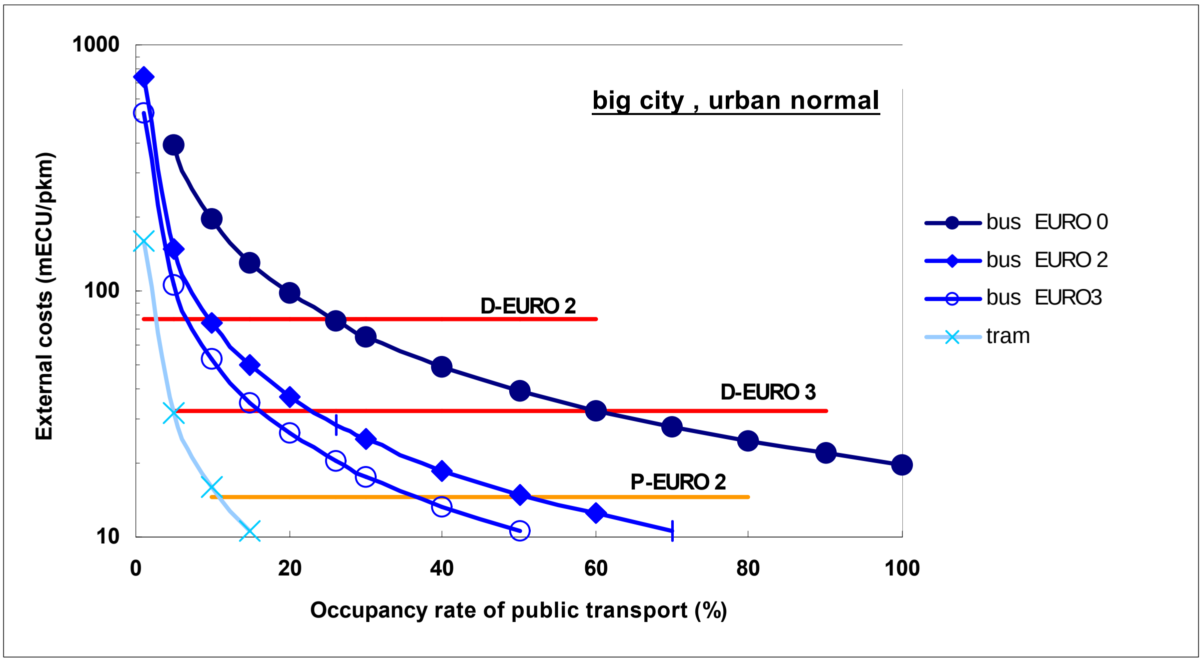

Figure 8 : external costs of public transport as a function of its seat occupancy rate

4. Conclusions

This paper shows that external costs of air pollutants from passenger cars and diesel busses are significant (e.g. compared to private fuel costs). It also indicates that there is not one single figure for the external costs of private cars, but that fuel, technology, location and traffic condition may lead to external costs that are up to 50 times as high compared to those of present day cars in rural, non-peak traffic. Especially the impacts of particulates on public health play a dominant role in these externalities.

This variety in external cost estimates is challenging for the development of efficiënt transport and environmental policies. Past and present policies aim at reducing tail-pipe emissions by regulatory standards. External cost estimates indeed decrease substantially by emission standard legislation. However, a quite remarkable result of the present exercise was precisely the doubling or tripling of congested traffic external costs with respect to normal urban traffic conditions. As without policy changes, congestion is likely to increase exponentially, it will reduce the benefits of emission standard legislation.

One way of dealing with the mobility problem is the promotion of public transport. Electric trams are regarded rightly as very environmentally friendly for urban transport. Present-day diesel buses perform relatively well provided their seat occupancy rate is high enough. As the impacts of particles is predominant in their case, the introduction of alternative fuel buses (CNG, LPG) would lead to significantly lower results.

Further publications

The data in this paper will be updated and published in January 1999 in a short interim report of the study ‘the external costs of transport’ for OSTC (see Acknoweledgements). This report will also include the progress on the estimation of external costs for noise, accidents and congestion.

Acknowledgements

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