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The potential for further controls of emissions from mobile sources in Europe

TSAP Report #4

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Version history

This report is the updated version of the draft report version 1.0 from June 2012, taking into account comments received from stakeholders and national experts. The following changes have been implemented:

It is now assumed that real-driving NO_x emissions from Euro 6 light duty diesel vehicles will decrease in two steps, namely to about 380 mg NO_x/km in a first step and to 120 mg NO_x/km in the second step. In the baseline scenario vehicles with these average emissions are assumed to be introduced by 2014 and 2017.

A range of sensitivity cases explores the implications of different assumptions about Euro 6 real-driving emissions on total emissions.

Further, inland vessels are now excluded from Stage IIIB or higher emission controls, and railcars and locomotives not subject to Stage IV controls.

Finally, this report explores the excess of 2010 NEC ceilings that can be attributed to higher than anticipated real-driving NO_x emissions from light duty diesel vehicles.

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Executive Summary

As one input to the revision of the Thematic Strategy on Air Pollution, this report presents an in-depth analysis of the factors that determine the evolution of emissions from mobile sources in Europe.

In 2005, emissions from mobile (road and non-road) sources contributed about 60% to total NO_x emissions in the EU, 20% to total PM2.5, and 30% to total VOC emissions. Road vehicles emitted more than 70% of NO_x and VOC of all mobile sources, and more than 60% of PM2.5.

From 2005 to 2010, implementation of EU legislation has reduced NO_x from mobile sources by 18%, PM by 21% and VOC by 34%. For NO_x, the decline is lower than the corresponding reductions from stationary sources (-26%), so that the relative importance of the transport sector has increased despite the EURO legislation on vehicle exhaust emission controls. The recent drop of NO_x emission is less than what was anticipated in the 2005 Thematic Strategy on Air Pollution. While emissions from gasoline cars and heavy duty diesel vehicles have decreased continuously, NO_x emissions from light duty diesel vehicles have been on the rise. This is the consequence of the non-decline of real-driving emissions despite the successive reduction of test cycle limit values, and because the number of diesel cars increased more than anticipated earlier. As a consequence, in 2010 NO_x emissions from light duty diesel vehicles were more than 60% higher compared to a situation where real-driving emissions of the EURO 2 to EURO 5 standards would have followed the type approval limit values.

According to the baseline projection, volumes of car and truck transport are expected to increase by 30% and 40%, respectively, until 2030 relative to 2005. However, the further reduction of unit emissions notably from heavy duty vehicles will lead to lower NO_x emissions in the EU-27. To what extent emissions will eventually decrease will largely depend on the future real-driving emissions from light duty diesel vehicles. If unit emissions of future vehicles will be within 150% of the type approval value from 2018 onwards, NO_x emissions from all road vehicles will be 60% and 85% lower in 2020 and 2030, respectively, compared to the 2005 level. If, however, unit emission of light duty diesel vehicles will not decrease under real-driving, total NO_x emissions will decrease only by 50% in 2020 and by 70% in 2030 compared to 2005, respectively. This means 400 kt higher NO_x emissions in 2020 and 900 kt more in 2030.

PM emissions from road transport are expected to fall by 62% in 2020 and by 70% in 2030, and VOC by up to 80% until 2030. For PM, the majority of emissions will then be caused by non-exhaust sources (tyre and brake wear, road abrasion). Total mass of PM emissions will strongly depend on the development of these sources.

For non-road mobile machinery, implementation of the agreed emission controls following the current schedule should cut NO_x emissions in 2020 by 40% and in 2030 by 60% compared to 2005. Emissions from $PM_{2.5}$ are projected to drop by 55% in 2020 and by 75% in 2030; the reduction of VOC emissions is estimated at 50% by 2020 and 60% until 2030. Least changes are expected from ships due to their long lifetime and the slow penetration of new technology.

If these changes materialize, emissions from mobile sources would decline faster than those of stationary sources. Especially road transport would lower its share in total emissions, e.g., for NO_x from 44% in 2005 to 17% in 2030, for PM from 14% to 7% and for VOC from 23% to 9%.

For road vehicles, the introduction of a hypothetical further EURO standard after 2020, with real-world emission factors around 20% below the EURO 6/VI limit values, could reduce NO_x emissions from road vehicles by up to 13% below the baseline projection for 2030.

Implications of these further measures on air quality at urban hot spots will be reported in Part 2 of this report at a later stage.

More information on the Internet

More information about the GAINS methodology and interactive access to input data and results is available at the Internet at http://gains.iiasa.ac.at/TSAP.

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List of acronyms

ACEA:	Association of European Automobile Manufacturers
ANFAC:	Association of Spanish Automobile Manufacturers
CLRTAP:	Convention on Long-Range Transport of Air Pollutants
ERMES:	European expert group on emissions from road vehicles
GDI:	Gasoline direct injection engine
HBEFA:	Handbook Emission Factors
HDV:	Heavy duty vehicles, i.e. a (heavy) truck, bus or coach.
JRC:	EU Joint Research Centre
LDV:	Light duty vehicle, i.e. a passenger car or a light commercial vehicle like a van.
MCE:	Maximum Control Efforts (scenario), i.e. including technical (exhaust) emission controls as well as structural changes.
MTFR:	Maximum Technical Feasible Reduction scenario
NEDC:	New European Driving Cycle
NRMM:	Non-road mobile machines
SCR:	Selective Catalytic Reduction
TFEIP:	Task Force Emission Inventories and Projection of the CLRTAP
UNFCCC:	UN Framework Convention for Climate Change

1 Introduction

In its 2005 Thematic Strategy on Air Pollution (TSAP), the European Commission outlined a road map to attain 'levels of air quality that do not give rise to significant negative impacts on, and risks to human health and environment' (CEC 2005). It established health and environmental objectives and emission reduction targets for the main pollutants.

In 2011, the European Commission has launched a comprehensive review and revision of its air policy, in particular of the 2005 Thematic Strategy on Air Pollution and its related legal instruments. A comprehensive review requires a more detailed evaluation of the different sources that contribute to current and future exposure (source apportionment) and estimate their specific reduction potentials.

Despite significant reductions in the past, air emissions from the transport sector, and in particular from road vehicles, are still a major source of air pollution relevant for human exposure. Although a successful implementation of emission legislation for road vehicles should lead to a further reduction of emissions from these sources, emission sources that have traditionally been more difficult to assess, such as non-exhaust and re-suspension, are also in the focus of the assessment.

This report presents estimates of the further emission control potential in the transport sector. Implications of further measures on air quality at urban hot spots will be reported in Part 2 of this report at a later stage.

The remainder of this report is organized as follows: First, the general method for calculating emissions from mobile sources is presented. Then, assumptions for the baseline scenario and a 'Maximum Technically Feasible Reduction' (MTFR) scenario are presented, followed by a discussion of the results for road and non-road mobile sources. The third chapter presents an alternative activity scenario, aiming at a massive decarbonisation of the transport sector (the 'decarbonisation' scenario), as presented recently in the Transport White Paper of the European Commission (EC 2011). This scenario illustrates dedicated efforts for a structural change in the transport sector. Finally, a 'Maximum Control Efforts' (MCE) scenarios explores the lowest levels of emissions from mobile sources that could be achieved through an ambitious decarbonisation strategy combined with the full application of all available end-of-pipe emission control measures. The final chapter is dedicated to sensitivity analyses exploring reduction potentials for NO_x emissions from light duty diesel vehicles under different assumptions on the future emission factors and the timing of implementation.

This report presents draft data as the basis for further consultation and discussion. Assumptions and results will be further elaborated over the course of the following months.

2 Methodology

This analysis employs the PRIMES, TREMOVE, COPERT, and GAINS models to estimate emissions from mobile sources and their reduction potentials for pollutant emissions. In general, emissions are analysed at the national level by road vehicle types (vehicle categories * fuel type), non-road mobile sources (building and construction machines, (diesel) locomotives, agricultural tractors, ships), including non-exhaust emissions and re-suspension. Estimates cover all relevant air pollutants: NO_x, NMVOC, CO, PM (as PM_{10}, $PM_{2.5}$, BC and OC), SO_2 and CO_2.

Total national emissions from vehicles in a given year are calculated according to

$$Em_p = \sum_{fc} (FC_{fc} * EF_{fcp})$$

with:

Em_p	total national emission of pollutant *p*. [Unit: kt]
FC_{fc} [Unit: PJ]	fuel consumption of vehicle category *c,* powered with fuel *f*
EF_{fcp}	average emission factor of pollutant *p* for vehicle category *c*, powered with fuel *f*. [Unit: g per MJ].

Input data for historic years are extracted from national statistics. Fuel consumption data are taken from EUROSTAT, and refer by convention to the fuel sold in a country. Hence, emissions resulting from that fuel use are allocated also to this country, irrespective of cross-border traffic. Scenarios for potential developments of fuel consumption are taken from the PRIMES model, further details below.

The average emission factor EF_{fcp} is calculated as the weighted sum of the emission factors per technology or emission concept *t* (i.e., identified by their EURO exhaust emission standard) for each combination of vehicle category *c* and fuel *f*:

$$EF_{p\,fc} = \sum_t (share_t * EF_{tp})_{fc}$$

with:

EF	average emission factor of pollutant *p* for vehicle category c, powered with fuel *f* [Unit: g per MJ];
share	share of this technology *t* in total fuel consumption for vehicle category *c*, powered with fuel *f* [Unit: %], also called control share;
EFt_{fcp}	average emission factor of pollutant *p* for technology *t*, vehicle category *c*, powered with fuel *f* [Unit: g per MJ].

Data for emission factors are taken from the latest version of the COPERT 4 database. Emission values are representative for real-world driving in the respective countries as established in the ARTEMIS project. Particular attention is devoted to the update of NO_x emission factors for diesel light and heavy duty vehicles as more and more measurement data on the performance of the EURO 5/V and eventually

EURO 6/VI technologies has become available. Primary emissions of particulate matter from exhaust, brake, clutch and tyre wear, and road abrasion are considered.

Base data on future transport activities (fuel consumption for the different vehicle categories) correspond to the TSAP-2012 baseline for the revision of the Thematic Strategy (cf. accompanying report by Amann et al. 2012), so that these calculations for the transport sector are consistent with the assumptions for other sectors and across countries.

3 Assumptions for the TSAP-2012 baseline scenario

3.1 Transport demand

The PRIMES model, providing consistent projections of supply and demand of energy, also estimates future transport demand by mode in European countries. This projection is used as basis for vehicle mileage, fuel demand and fuel intensity changes.

Basis for the calculation of future emissions is the PRIMES 2010 Reference scenario, which is also used for the Transport White Paper, the Low-carbon Economy Roadmap and the 2050 Energy Roadmap (EC 2011b; EC 2011a). For the outlook to 2050, figures from the reference case of the 2050 'Roadmap for moving to a competitive low carbon economy' of DG-CLIMA (EC 2011a) are used.

As a sensitivity case, this report employs a stringent climate policy (decarbonisation) scenario, i.e., the 'Global Action with Effective and Widely accepted Technology' scenario, which has been developed with the PRIMES model for the communication of the European Commission on a 'A roadmap for moving to a competitive low carbon economy in 2050' (EC 2011a).

According to the PRIMES reference projection, car travel will remain the dominant passenger transport mode, though its share will decline slowly in the EU-27 from 73% in 2005 to 67% in 2050. Air travel will increase its modal share from 8% to 15% over the same period, doubling its transport volume between 2005 and 2030. Rail travel grows by 39% until 2030, and its modal share stays at 8%. Total passenger transport volume is projected to increase by 30% in the EU-15, and twice as much in new Member States.

Freight transport volume is projected to grow by 38% in the EU-27 until 2030. No major structural shifts are expected. Trucks remain at a share of 73%, and rail and inland vessels carry 17% and 10% of the total freight transport volume in the EU-27 over the whole period.

3.2 Fuel consumption

Fuel consumption data for historic years are taken from EUROSTAT statistics for each country. For future years, the PRIMES energy model provides supply and demand projections of energy by fuel type consistently for all sectors across all Member States. For the transport sector, PRIMES specifies fuel consumption, i.e., how much gasoline, diesel, LPG, CNG, H_2 (where relevant) and eventually electricity is consumed by transportation (Figure 3.1). Fuel demand for air, rail and inland navigation is projected for both passenger and freight transport. For agricultural and forestry machines, fuel demand is coupled to the overall activity in the agricultural sector.

Likewise, the fuel demand for construction and industry mobile machinery is linked proportionally to the overall fuel demand in the industry sector.

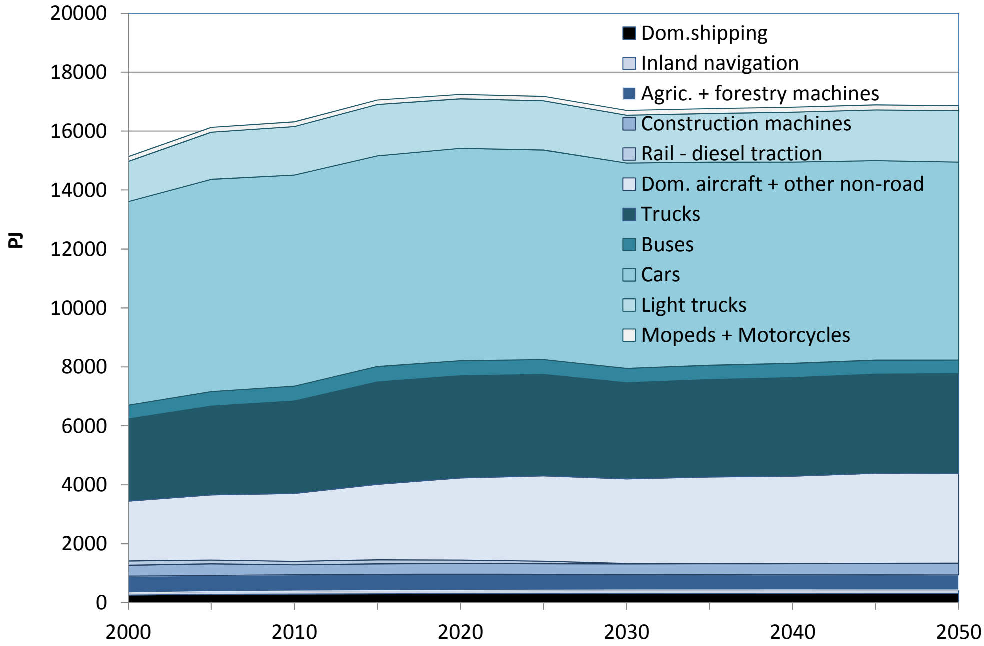

Figure 3.1: Development of fuel consumption by mobile sources in the EU-27 under the baseline scenario. Unit: PJ. Source: PRIMES (EC 2011).

For some transport modes, consumption data can used directly for this analysis, notably for buses, gasoline powered cars, railways and aircraft. However, comparison with national traffic models and statistical data has proven that in particular the distribution of diesel fuel across cars, light trucks and heavy trucks needs readjustment. This is done based on the fleet turnover module of the TREMOVE model, and fuel efficiency data from the COPERT model (averaged per vehicle category and fuel type in each country). Calibration to total fuel consumption provides a triangulated distribution of diesel fuel across vehicle categories for each country. This recalibration is important for the emission calculations, since projected fuel consumption by vehicle category and fuel type is key input (Table 3-1). Further details on the calibration and fleet turnover are described below.

3.2.1 Road transport

Road vehicles consume about 16% of total final energy in the EU-27 in the year 2005. This level is projected to increase by 4% until 2020, and then to return to the earlier level from 2030 onwards. Biggest growth is expected for light and heavy trucks, while total consumption by cars is supposed to stay roughly constant until 2020 and then to decrease to 93% of the 2005 level in 2050. Gasoline consumption of cars is expected to decline by 12% and 14% until 2020 and 2030, respectively, while consumption of diesel cars grows by about 10%. In the baseline, electric cars enter the market from 2030 onwards in sizeable numbers, but their share in car transport volume remains below 1% over the period.

Table 3-1: Fuel consumption for road and non-road vehicles, trends relative to the year 2005 and share of mobile sources in total energy consumption in EU27 at selected years according to the Baseline scenario.

Fuel consumption	*PJ* 2005	*PJ* 2020	*PJ* 2030	*PJ* 2050	*2005=100%* 2020	2030	2050
Dom.shipping	286	309	320	320	108%	112%	112%
Inland navigation	90	112	111	111	124%	123%	123%
Agric. + forestry machines	546	552	522	512	101%	96%	94%
Construction machines	398	357	362	395	90%	91%	99%
Rail - diesel traction	129	117	17	4	91%	13%	3%
Rail - electric traction	266	302	339	354	114%	127%	133%
Dom. aircraft + other non-road	2208	2786	2871	3042	126%	130%	138%
Heavy trucks - diesel	3005	3454	3246	3375	115%	108%	112%
Cars and light trucks - gasoline	4634	4098	3975	3935	88%	86%	85%
Cars and light trucks - diesel	3967	4490	4333	4228	113%	109%	107%
Cars and light trucks - electric	1	1	2	36	126%	394%	5748%
Mopeds + Motorcycles	162	148	164	167	91%	101%	103%
Buses + all other	702	816	774	676	116%	110%	96%
Sum Non-road + Road	16393	17543	17037	17156	107%	104%	105%
Non-road in Total all sectors	5%	6%	6%	6%			
Road in Total all sectors	16%	18%	17%	17%			

3.2.2 Non-road sources

Non-road sources consume about 5% of total final energy in the EU-27 in the year 2005. Their consumption is expected to increase by 16% until 2020. Growth is essentially driven by increasing domestic air traffic[1] that accounts for more than half of total non-road fuel consumption. Efficiency improvements and higher load factors for aircraft partially compensate for the volume growth; by 2030 fuel demand for aircraft is projected one third higher in the EU-27 than in 2005. Fuel consumption by inland vessels and ships is assumed to grow by about 15% over the next 25 years, and then to level off. Rail diesel traction is assumed to be phased out by 2030, while electric traction is expanded. The complete electrification of rail traction leads to a reduction of the energy intensities of passenger and freight traction by about one third until 2030. Thus, total energy demand for passenger rail will stay constant, while rail freight energy demand drops by more than 10% in 2030. Consumption by machines in agriculture, forestry, construction and industry is assumed to remain roughly constant. Together, they account for about one fifth of non-road total fuel consumption.

[1] These numbers refer to domestic air and ship traffic only. Consumption and emissions from international air and ship traffic are excluded, in line with the conventions of UNFCCC and CLRTAP.

3.3 Fleet composition and turn-over

The fleet composition for the historic years is based on the DG ENV "FLEETS" project (Ntziachristos et al. 2008), which produced a consistent dataset of detailed vehicle and activity information for road transport for each Member State. FLEETS incorporated national statistics that are used for submissions of road transport-related inventories to UNFCCC and CLRTAP, as well as international sources, such as ACEA, ANFAC, the first version of the CO_2 monitoring database[2], and others. The FLEETS dataset has been introduced in the latest version of the TREMOVE software (v3.3.2).

The FLEET dataset includes:

- Number of vehicles per age group, for passenger cars, light commercial vehicles, heavy duty vehicles, mopeds, and motorcycles.
- Number of vehicles per technology class (EURO standard), by fuel use (petrol, diesel, LPG, CNG, hybrids, electric), and other characteristics (engine capacity or weight).
- Annual mileage of vehicles as a function of vehicle age for the main vehicle categories.
- Mean travelling speeds and mileage fractions in urban, rural, and highway driving.

This dataset has been further updated and reviewed in the framework of the LIFE EC4MACS project (Amann et al. 2011) and for the current project, including

- Update of fleet data for 2005-2010, using data on new registrations from the new CO_2 monitoring database according to Regulation 443/2009/EC;
- Feedbacks from national experts in the framework of the Task Force on Emission Inventories and Projections (TFEIP);
- Information provided by national experts during bilateral consultations on the GAINS input data with Bulgaria, France, Poland, Portugal and Romania.

The corrected dataset has been cross-checked with national experts within the TFEIP activities (Mellios, Papageorgiou, and Ntziachristos 2009). Results from the final bottom-up calculation of fuel consumption derived from this dataset and the COPERT 4 consumption factors have been harmonized with top-down calculations of total energy consumption per fuel, and mileage adjustments, which provides an internally consistent dataset of fleet composition that also matches the fuel sold estimation. This balanced dataset is the most elaborate independent dataset on such activities in Europe. Differences in emissions between national submissions to UNFCCC and calculations conducted with the current dataset and COPERT 4 emission and consumption factors range between 0 and 7%, mainly for VOC (Table 3-2). Discrepancies are likely to result from misallocations of evaporative emissions in some national datasets.

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[2] Decision No 1753/2000/EC of the European Parliament.

Table 3-2: Comparison of emission calculations conducted with the current dataset ('centralised' data) and national CLRTAP submissions in 2010

	National 2000	Centralised 2000	Dev (%)	Countries not included	National 2005	Centralised 2005	Dev (%)	Countries not included
CO	15133	14898	-2	BG,CZ,GR,HU LT,LU,MT,PL,RO	11241	11206	0	LU, MT
VOC	2503	2318	-7	BG,CZ,GR,HU LT,LU,PL,RO	1782	1627	-9	LU
NOx	4901	4889	0	BG,CZ,GR,HU,LT LU,PL,RO	4552	4623	2	LU
$PM_{2.5}$	262	274	4	BG,CZ,GR,HU,LT LU,PL,RO	250	252	1	BG, GR, LU, RO
CO_2	842852	854144	1	CY,LU,MT	896018	908528	1	CY, LU, MT

Future fleet turnover has been derived for the reference stock and activity dataset. Historic data are used to estimate the lifetime functions of vehicles in the stock, i.e., the survival probability of vehicles according to their age. This survival probability is projected to future years to provide the number of scrapped vehicles. Total stock growth per year is harmonized with the PRIMES projection. The difference between total stock growth and new registrations delivers the number of vehicles that are registered every year in the total stock. These can be either new or second-hand cars. The ratio of the two is based on evidence that has been collected in several research projects (Mehlhart et al. 2011). Depending the registration year, vehicles are allocated to the technology class (EURO standard) applicable to the first year of vehicle registration. A detailed description of the methodology can be found in (Ntziachristos and Kouridis 2008).

An example result is shown in Figure 3.2 for gasoline and diesel cars in Germany. With the gradual introduction of new vehicles the fleet, and notably the respective shares in mileage and fuel consumed, comply with more advanced emission control standards.

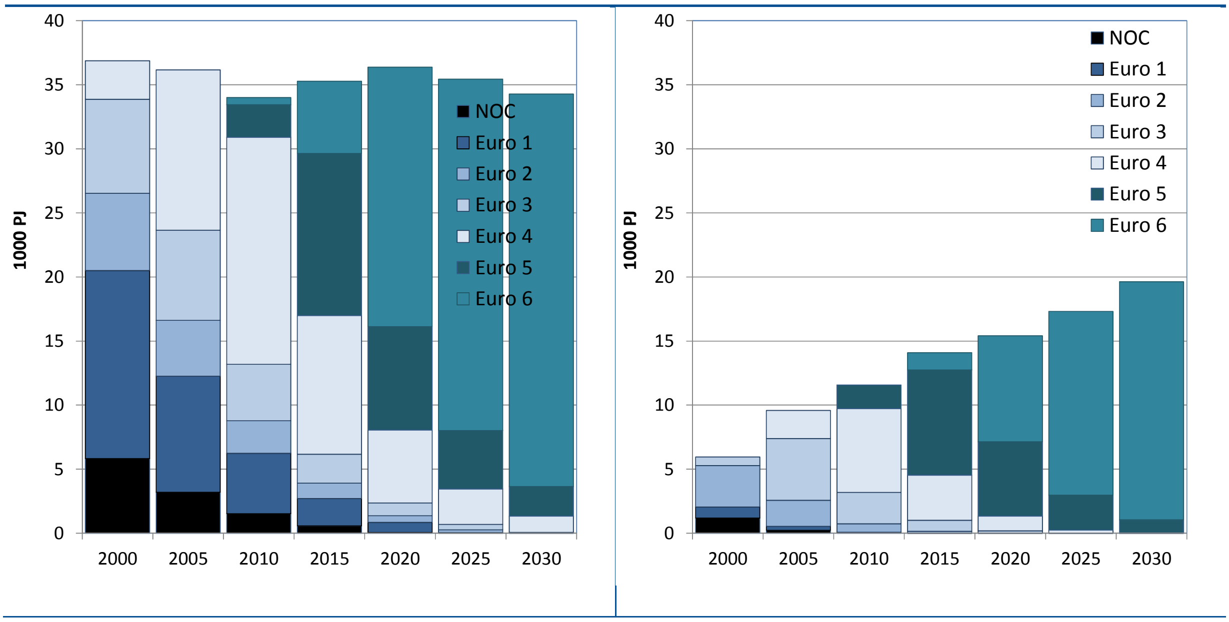

Figure 3.2: Fuel consumption by gasoline (left) and diesel (right) cars as a function of technology and time in Germany in the baseline scenario. EURO 6 technology will cover more than 95% of the total stock after 2030.

During the consultations with national experts undertaken for the EC4MACS project, misallocations of second-hand registrations have been detected that may significantly affect the calculation of total emissions. According to (Mehlhart et al. 2011), the average age of second-hand registrations is around seven years, with many vehicles already more than 10 years old when first registered in a country. This means that a newly registered vehicle can already be two generations old in terms of its exhaust emission technology compared to the actual emission limit in force at the time of the registration. To take this into account, an algorithm has been developed for countries where second-hand registrations are important (BG, CY, CZ, EE, GR, LT, LV, MT, PL, RO, and SK). The original age distribution of second-hand vehicles derived from (Mehlhart et al. 2011) is adjusted over time following changes in per-capita GDP. It is assumed that with growing GDP per capita less old and more new vehicles are registered, and that the mean age of used vehicles decreases. The algorithm considers a range of boundary conditions, i.e., total stock growth estimated from the PRIMES projection, new registrations of the CO_2 monitoring database, scrapped vehicles estimated by the algorithm, and per-capita GDP change over the years. The algorithm provides an internally consistent dataset, and a much more detailed and coherent projection of fleet composition than what is currently offered by PRIMES or PRIMES-TREMOVE.

In addition to the autonomous technology replacement, the TSAP-2012 baseline scenario assumes progressing introduction of fuel efficiency technologies to meet greenhouse gas targets. Three technologies are expected to become widely popular for passenger cars: Hybrid diesels will complement the market of conventional diesel cars. They appear in significant numbers in 2015, and by 2030 they would account for 50% of total diesel passenger car mileage. This ratio remains rather constant through 2050. For conventional diesel cars, a continuation of the trend of fuel efficiency improvements of ~2% per year is assumed up to 2030, which will decline to 1% per year thereafter. This would result from engine and vehicle technology improvements as well as through downsizing. For gasoline passenger cars, hybrid and direct injection (GDI) technologies will enter the market. They result in much better fuel efficiency compared to the conventional technology. In 2030, almost equal shares are expected for conventional and GDI gasoline cars, while hybrids represent almost half of either of the two. Fuel efficiencies of conventional gasoline cars is expected to improve at the same rate as that of diesel cars. Similar efficiency improvement rates are expected for the other vehicle categories. Most trucks and buses will be operated by diesel engines.

These technology improvements apply to a volume of passenger and freight activities that grows annually by 1.26% and 1.38%, respectively, in the PRIMES reference scenario. Electricity will continue to play a minor role in the baseline scenario, providing less than 1% of total passenger transport by the year 2050, and 4.4% of freight transport by electric trains.

3.4 Emission factors

Emission factors for the different EURO standards have been calculated with the latest (v9.0) version of the COPERT 4 model[3]. This is the most widespread software in Europe for the calculation of emissions from road transport, and it is used by 22 out of the 27 Member States for their official submissions of inventory data to CLRTAP and/or UNFCCC. COPERT contains a detailed methodology to estimate tailpipe, fuel evaporation, and non-exhaust PM (brake and tyre-wear) emissions. Particulates from road abrasion are estimated, but resuspension is not included. Emission factors are developed in conjunction with other models (e.g., HBEFA and VERSIT+) through the ERMES working group, facilitated by JRC. There is an extensive list of scientific papers and research reports used for COPERT emission factor development and validation. A summary of the quality of emission predictions is given by (Smit, Ntziachristos, and Boulter 2010).

The TSAP-2012 baseline employs fleet and activity data as described in the previous section, complemented by hybrid diesel cars, electric and hydrogen cars that are currently not included in COPERT. Exhaust and evaporative emissions for electric and hydrogen cars were assumed to be zero. Input data for hot emission factors (average speed and shares in urban, rural, and highway driving) were obtained from national submissions to the FLEETS project. Ambient temperature conditions for each country were used to estimate cold-start over-emissions and fuel evaporation.

Calculations were conducted for individual years taking into account the impacts of fuel quality on emissions and of vehicle age on emission degradation. However, results are shown here only for intervals of five years. Also, all emission factors were aggregated to average g/km, weighing the actual urban, rural, and highway driving conditions in each country.

Since the GAINS model operates with emission factors averaged over the whole lifetime of the vehicle, effects of fuel, age and driving patterns have to be averaged. For this purpose, a value corresponding to five years after the introduction of the emission limit was chosen as a representative aggregated emission factor.

A comparison of the aggregated real-world emission factors used in this study with emission-limit values reveals significant differences notably in the NO_x emissions of diesel passenger cars, where real-driving emissions exceed the test cycle emission limit values several times

Note that the difference in emissions results only from different driving conditions. All vehicles comply with the legislative requirements, i.e., they are below the respective limit value for the legislative driving cycle (NEDC from EURO 3 onwards). The higher real-world emissions emerge from the fact that real-world driving cycles include engine operation modes that are not or much less used in the type-approval

[3] http://www.emisia.com/copert/General.html

procedure. In such operation modes, emission rates can be substantially higher than the type-approval limit values.

Table 3-3: Real-world driving emission factors including cold-start excess emissions for the most important vehicle categories and pollutants, differentiated by emission control stage assumed for the baseline scenario. Data are country-specific, and the shown data refer to France. Evaporative emissions of NMVOC as well as PM emissions from tyre and brake wear and road abrasion are not included in this table.

	Passenger car - gasoline				**Passenger car - diesel**			
	NOx	**PM2.5**	**CO**	**NMVOC**	**NOx**	**PM2.5**	**CO**	**NMVOC**
	g/MJ	mg/MJ	g/MJ	g/MJ	g/MJ	mg/MJ	g/MJ	g/MJ
No control	0.841	0.905	4.775	0.857	0.269	86.808	0.246	0.060
Euro 1	0.171	0.955	1.839	0.207	0.289	34.395	0.158	0.021
Euro 2	0.101	1.000	1.184	0.104	0.290	21.478	0.105	0.020
Euro 3	0.042	0.428	1.034	0.053	0.335	17.900	0.036	0.010
Euro 4	0.025	0.431	0.349	0.032	0.268	16.557	0.039	0.007
Euro 5	0.025	0.498	0.408	0.045	0.376	0.899	0.044	0.008
Euro 6	0.024	0.439	0.364	0.041	E6.1: 0.171 E6.2: 0.054	0.999	0.049	0.009
	Light duty truck - gasoline				**Light duty truck - diesel**			
	NOx	**PM2.5**	**CO**	**NMVOC**	**NOx**	**PM2.5**	**CO**	**NMVOC**
	g/MJ	mg/MJ	g/MJ	g/MJ	g/MJ	mg/MJ	g/MJ	g/MJ
No controls	0.770	0.674	5.840	0.788	0.425	88.417	0.334	0.036
Euro 1	0.127	0.574	1.956	0.122	0.372	31.513	0.157	0.043
Euro 2	0.055	0.574	1.323	0.052	0.372	31.513	0.157	0.045
Euro 3	0.032	0.255	1.173	0.031	0.309	23.139	0.138	0.030
Euro 4	0.018	0.269	0.483	0.018	0.249	13.017	0.113	0.011
Euro 5	0.016	0.306	0.548	0.025	0.346	0.749	0.113	0.012
Euro 6	0.018	0.337	0.605	0.028	E6.1: 0.180 E6.2: 0.057	0.763	0.116	0.012
	Motorcycle - gasoline				**Heavy duty truck - diesel**			
	NOx	**PM2.5**	**CO**	**NMVOC**	**NOx**	**PM2.5**	**CO**	**NMVOC**
	g/MJ	mg/MJ	g/MJ	g/MJ	g/MJ	mg/MJ	g/MJ	g/MJ
No controls	0.109	57.215	13.629	4.025	1.012	40.126	0.200	0.072
Euro 1	0.278	16.021	7.546	0.691	0.791	32.297	0.186	0.056
Euro 2	0.254	22.594	3.581	1.100	0.856	16.020	0.165	0.037
Euro 3	0.111	3.237	1.699	0.219	0.657	14.656	0.175	0.033
Euro 4	To be implemented for the final calculations				0.433	2.909	0.012	0.001
Euro 5					0.248	2.934	0.012	0.001
Euro 6					0.032	0.149	0.012	0.001

For average emission factors of forthcoming standards and technologies, the following assumptions are taken in this report.

3.4.1 Emission factors for light duty vehicles

EURO 5 emission factors have been based on preliminary assessments derived from recent measurements. In particular, measured NO_x emissions of EURO 5 diesel cars are higher than those of EURO 4 and EURO 3 cars, and exceed the limit value defined for type approval several times (Hausberger 2010). This analysis adopts an average value of about 870 mg NO_x/km, i.e. almost five times higher than the nominal limit value. Consolidated EURO 5 emission factors are expected to be derived by the ERMES group later during 2012.

There is uncertainty about the average EURO 6 NO_x emission factor under real-driving conditions for future light duty diesel vehicles. For the baseline scenario it is assumed that real-driving emissions of a first generation of Euro 6.1 vehicle will be about 380 mg NO_x/km, i.e., by the same rate lower than the Euro 5 value as the emission limits are lower. It is further assumed that for the second generation of Euro 6.2 vehicles the type approval testing will be completed by, e.g., on-board PEMS or a random cycle tests. As a consequence, new vehicle types from 2017 onwards are assumed to emit 120 mg NO_x/km under real-driving. Early demonstration vehicles have shown that SCR technology with injection of appropriate amounts of urea could deliver large reductions in NO_x emissions over Euro 5 vehicles, both for type-approval and real-world cycles (Demuynck et al. 2012; Hausberger 2012). Implications of different timing and levels of the future real-driving emissions from Euro 6 light duty diesel vehicles are explored in sensitivity analyses.

For all other pollutants and for gasoline cars, EURO 6 emission factors are derived by applying the ratio between EURO 6 and EURO 5 type approval limit values to the real-world EURO 5 emission factor. This is not problematic, as nominal limit values have been respected in the past, so that the difference to real-world driving conditions is less relevant.

With regard to PM, all post EURO 5 diesel cars are equipped with efficient particle filters that keep PM unit emissions below 1 mg/km. The same holds for gasoline cars, except for GDI engines that are considered to emit 5 mg/km at EURO 5 and EURO 6 levels before 2017. After this date, we consider that sufficient measures will have been taken (e.g., by means of gasoline particle filters) that will allow GDI vehicles to reduce emissions below 1 mg/km.

To explore the scope for further cost-effective emission controls for road transport within the review of the Thematic Strategy on Air Pollution, a hypothetical further emission control stage has been defined with placeholder values for further emission reduction efficiencies and costs. Obviously, these stages are not included in the current legislation scenario. These options serve in the modelling exercise as a means to determine whether a technology that would deliver the assumed emission reductions at the assumed costs would be cost-effective in relation to environmental targets and the further measures that are available for other sources. At this stage, the efficiency and cost numbers used for the theoretical assessment are not related to specific technologies. Along these lines, placeholder emission factors for a hypothetical EURO standard have been set at 65 mg NO_x/km (e.g., to bridge the difference between gasoline and diesel cars). For PM, the same emission standard as Euro 5/6 has been assumed (i.e., 4.5 mg/km). The EURO 5/6 real-world emission factor is already a fraction of the emission limit due to the efficient performance of DPFs and the need to meet the stringent particle number limit (6×10^{11} km^{-1}). The real-world emission factor of the additional control stage is assumed to further decrease by 50% over Euro 6 due to technology improvement and further optimization of engines and after-treatment, despite the emission limit remaining the same. It is assumed that such an additional stage could be introduced from 2020 onwards in the MTFR and MCE scenarios.

3.4.2 Emission factors for heavy duty vehicles

EURO V emission factors for trucks are based on the COPERT 4/HBEFA 3.1 functions; emissions are further reduced for EURO VI proportional to the ratios of the limit values.

The hypothetical additional control stage is assumed to lead to further NO_x reduction of 30% over EURO VI, e.g. by a better control of slow-speed/low-temperature emissions or higher dosage of urea. PM emission factors would remain at the very low level of 3 mg/km of EURO VI. Similar to passenger cars, this level is actually below the emission limit because already the Euro VI technology is expected to be fully equipped with DPFs that can reduce the levels of Euro V PM by 80-90%. It is assumed that the additional stage could be introduced from 2020 onwards in the MTFR and MCE scenarios.

3.4.3 Emission factors for powered two-wheelers

The latest developments concerning powered two-wheeler emission limits have been also introduced, following the recent vote of the European Parliament on new emission control regulation, based on and extending the European Commission's proposal COM/2010/542. Emission limits up to EURO 6 will be introduced, with a hypothetical further step by 2030 in the MTFR and MCE scenarios. NO_x unit emissions are considered to drop by 25%, 60%, 70%, and 92.5% for the different stages. PM emissions follow reductions in VOC, dropping by equal amounts as NOx[4]. No separate emission limits for mopeds have been considered as their relative contribution to total emissions will decline in the future when they are gradually replaced by small motorcycles.

3.4.4 Non-exhaust emissions

Table 3-4 summarizes assumptions for abrasion, brake and tyre wear for the different vehicle categories. Due to lack of detailed country information the non-exhaust particulate emission factors apply to all European countries alike. The exception is abrasion for light duty vehicles in Nordic countries (Finland, Norway and Sweden). These countries allow or mandate the use of studded tyres for light duty vehicles during winter. This causes a much higher road wear which is accounted for in this analysis.

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[4] Will be implemented for the final version of the emission calculation. No significant change in total emissions expected.

Table 3-4: Emission factors for road abrasion, brake and tyre wear by size fraction for powered two-wheelers, light and heavy duty vehicles and countries without studded tyres.

	Abrasion			Brake wear			Tyre wear		
	TSP mg/km	%PM10 in TSP	%PM2.5 in TSP	TSP mg/km	%PM10 in TSP	%PM2.5 in TSP	TSP mg/km	%PM10 in TSP	%PM2.5 in TSP
PTW	5	50%	27%	2	83%	58%	29	10%	1%
LDV	14	50%	28%	5	82%	58%	68	10%	1%
HDV	68	50%	28%	20	83%	58%	471	10%	1%

Beyond current legislation, i.e., for the MTFR and MCE scenarios, this analysis also considers reductions of non-exhaust PM emission factors. Two steps are assumed, which will reduce emissions by 30% in 2020 and by 50% in 2030. Measures include eco-tyres and new materials for brake pads and discs. Emission factors for road abrasion remain however unchanged due to a lack of feasible and effective measures for widespread application.

3.5 Emission factors for non-road mobile machinery

Emission factors for non-road mobile machinery (NRMM) are assumed according the relevant legislation. Stage IIIB mandates a stringent limit of PM emissions that requires after-treatment and consequently low-sulphur fuel. Stage IV, in addition, requires De-NOx techniques, bringing unit emissions down to the Euro V level for heavy duty vehicles. However, engines for use in inland vessels only need to comply with Stage IIIA, engines for railcars and locomotives only with Stage IIIB.

Therefore, the MTFR and MCE scenarios assume that Stage IV will be extended to inland vessels and railcars and locomotives, hypothetical Stage V is assumed from 2020 onwards to illustrate further reduction potential for the other machine categories. This stage is assumed to reduce specific PM emissions by almost two thirds below the previous stage, and reduce specific NO_x emissions from diesel machines used in agriculture, forestry, industry and construction by more than half.

4 Future emissions in the transport sector

4.1 Emission scenarios

To outline the possible range of future emissions from the transport sector, this report presents two scenarios for different sets of emission control legislation. Sensitivity analyses explore how different assumptions on transport demand and activities, as well as different assumptions on the introduction and effectiveness of new emission control technologies would impact future emissions from this sector.

- The baseline scenario employs the draft TSAP-2012 baseline scenario that is reported in TSAP Report #1 (Amann et al. 2012). It assumes the fuel consumption development as projected by the PRIMES 2010 reference scenario, coupled with the standard fleet turnover as modelled with TREMOVE, and the emission factors provided by COPERT 4 up to EURO 6/VI.
- The 'Maximum Technically Feasible Reduction' (MTFR) scenario is built on the same activity and fleet turnover dynamics, but assumes introduction of the hypothetical further standards beyond EURO 6 and Stage IV for light-duty road vehicles and NRMM respectively, from 2020 onwards.

This report presents the development for the main pollutants for the relevant vehicle categories. Data and graphs are shown for the EU-27 as a whole. Country-specific details are available on the Internet from the GAINS-online web site http://gains.iiasa.ac.at/models/index.html. Summary tables for SNAP sectors 7 (road) and 8 (non-road) are provided in the Annex.

4.2 NO_x emissions

Implementation of the current emission legislation should lead to a sharp decline in total NO_x emissions from road and non-road mobile sources (Figure 4.1, Table 4-1). With the assumptions on the effectiveness of latest emission controls as described above, NO_x emissions would decline in 2020 by almost 60% below the 2005 level, in 2030 by 80% and in 2050 by 85%.

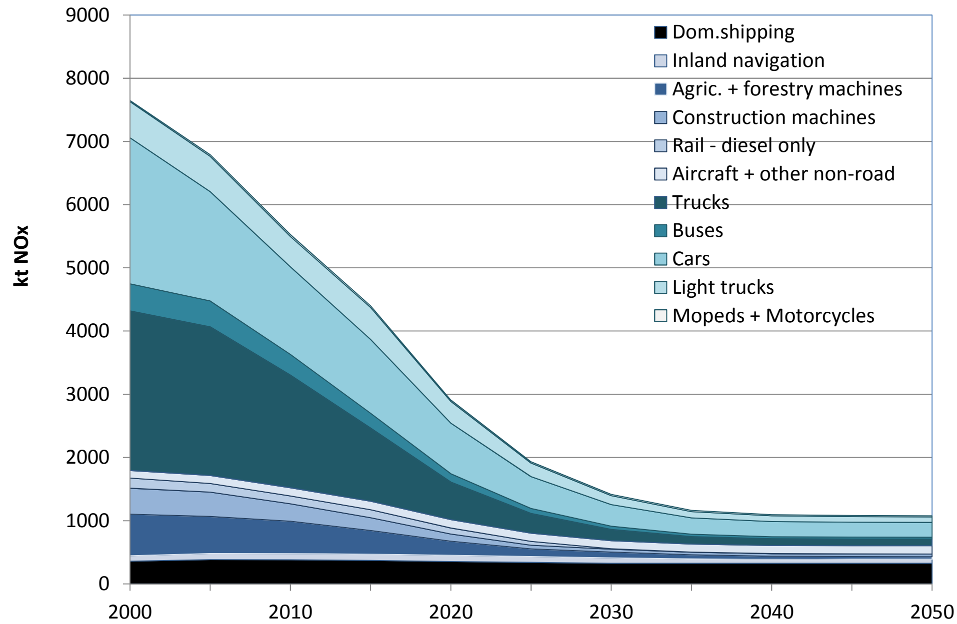

Figure 4.1: Development of NO_x emissions from mobile sources in the EU-27 for the TSAP-2012 the Baseline scenario

Table 4-1: NO_x emissions from road and non-road sources in the TSAP-2012 baseline and MTFR scenarios, changes relative to the year 2005, and the shares of mobile sources in total emissions in the EU-27 at selected years (kilotons).

		TSAP-2012 baseline scenario			*Draft MTFR scenario*		
	2005	2020	2030	2050	2020	2030	2050
Dom.shipping	386	354	327	327	354	327	327
Inland navigation	96	100	86	65	97	73	23
Agriculture + forestry machines	585	223	90	40	222	80	22
Construction machines	385	113	46	42	112	37	29
Rail – diesel traction only	137	95	9	2	93	7	0
Aircraft + other non-road	127	132	125	129	132	125	129
Heavy trucks - diesel	2349	595	180	106	591	165	87
Cars and light trucks - gasoline	929	133	87	81	133	87	81
Cars and light trucks - diesel	1289	994	386	234	858	265	147
Mopeds + motorcycles	26	22	20	18	22	20	18
Buses + all other	482	149	61	34	147	54	27
Sum Non-road + Road	6791	2910	1416	1078	2761	1240	890
Change vs. 2005	0%	-57%	-79%	-84%	-59%	-82%	-87%
Non-road in Total all sectors	15%	18%	17%	17%	22%	23%	23%
Road in Total all sectors	44%	34%	18%	13%	38%	21%	15%

4.2.1 Road transport

Road transport is the single biggest source of emissions of NO_x, contributing about 44% to the total in the EU-27 in 2005. Diesel vehicles in general are the main source;

heavy trucks, light trucks and diesel cars are the vehicle categories with the highest share in emissions, followed by gasoline cars and buses.

Baseline trends

NO_x emissions from gasoline cars should decrease quickly with the effective introduction of the assumed emission controls. In 2020 and 2030, emissions will amount to 14% and 9% of the current levels. Likewise, the gradual penetration of EURO IV, V and VI emission control stages is expected to reduce emissions from heavy trucks and diesel buses to 25-31% of the current level in 2020, and further to 8-13% in 2030. Only few further controls will be applied to motorcycles; however, their share in total emissions from road transport remains in the order of 1% over the period.

So far, NO_x regulations for diesel cars and light trucks have been proven ineffective under real-world driving conditions (Hausberger et al. 2009; Carslaw et al. 2011). Together with the strong growth of fleet and mileage for diesel cars, this has made them the second highest emitting vehicle category. The activity is assumed to grow by another 13% until 2020 relative to 2005 in the TSAP-2012 baseline scenario. With the introduction of EURO 6 it is assumed that NO_x unit emissions from light duty diesel vehicles under real-driving will decline from 2015 onwards and eventually come close to the legislative limit value, implying a reduction of 86% below the real-world EURO 5 value (in grams per km). As a consequence, total NO_x emissions from light duty diesel vehicles are projected to decrease by 23% in 2020 and by 70% by 2030 relative to the year 2005.

Total emissions will scale with the projected activity once the latest emission control technologies will have fully penetrated the fleet. Hence, the rate of decline slows down beyond 2030. Emissions from all road vehicles together are expected to decline by 63%, 86% and 90% by 2020, 2030 and 2050, respectively. As this reduction is higher than the change in national total emissions, the share of road transport in total emissions is expected to decline to one third in 2020 and to less than one fifth from 2030 onwards.

The Maximum Technically Feasible Reductions

The additional controls that are assumed in the MTFR scenario (i.e., introduction of a further emission control stage from 2020 onwards) would have a significant impact on emissions from light duty diesel vehicles. This measure could bring down emissions by an additional 150 kt and 175 kt in the EU-27 in 2020 and 2030, respectively, which corresponds to 5% and 12% of total NO_x emissions from mobile (road and non-road) sources in the baseline case. In 2050, this measure could eliminate 90 kt, and thereby lower emissions by another 15% below baseline.

4.2.2 Non-road sources

Non-road sources emitted about 15% of total NO_x emissions in the EU-27 in 2005. Ships and mobile machines used for agriculture, forestry, in industry and construction contributed the most.

Baseline

Emissions from these diesel powered machines are expected to decline by 60% to 70% until 2020 with the implementation of Stages IIIB and IV for mobile machinery. The turnover and hence the penetration of new emission controls is much slower for ships; so that their emissions decrease only by 6% and 14% until 2020 and 2030, respectively. As a consequence, coastal and inland shipping become the single biggest source category among non-road vehicles.

Few emission controls are projected for LTO emissions from aircraft, essentially compensating the assumed growth in activity. Consequently, emissions remain close to the 2005 level throughout the period. Emissions from diesel locomotives and railcars are projected to decline by more than 30% until 2020. After this period, the baseline assumes phase-out of diesel traction, and emissions would fall in 2030 to only 6% of the 2005 level.

Overall, emissions from non-road vehicles are expected to decline by 40%, 60% and 65% until 2020, 2030 and 2050, respectively. This is similar to the trend in total national emissions, so that these sources maintain their share of about 15% throughout the period.

The Maximum Technically Feasible Reductions

Additional emission controls - without premature scrapping of existing equipment – would have largest impacts on emissions from diesel powered mobile machines in agriculture and forestry, as well as in industry and the construction sector. This could reduce their emissions by 10% (agriculture and forestry) and 20% (industry and construction) by 2030 and by 44% and 30% in 2050 below baseline. However, these sectors are projected to contribute only 20% to total non-road emissions in 2030 in the TSAP-2012 baseline, while vessels and aircraft contribute 60% and 20%, respectively. Thus, without effective controls for these sources, non-road emissions cannot be reduced much. The potentials for these sources will be reviewed in the final report.

4.3 PM emissions

The implementation of current legislation should lead to a sharp decline in PM emissions from mobile sources. PM2.5 emissions would be lower by 60% in 2020 and by 74% in 2050, compared to 2005 (Table 4-2). Particulate emissions from combustion engines are usually smaller than 2.5 µm in aerodynamic diameter, so that exhaust emissions are essentially equal for the PM_{10} and $PM_{2.5}$ size fractions. Differences are significant for road abrasion, tyre, brake and gear wear, for which the PM_{10} fraction is about 2.5 times higher in weight compared to the $PM_{2.5}$ fraction.

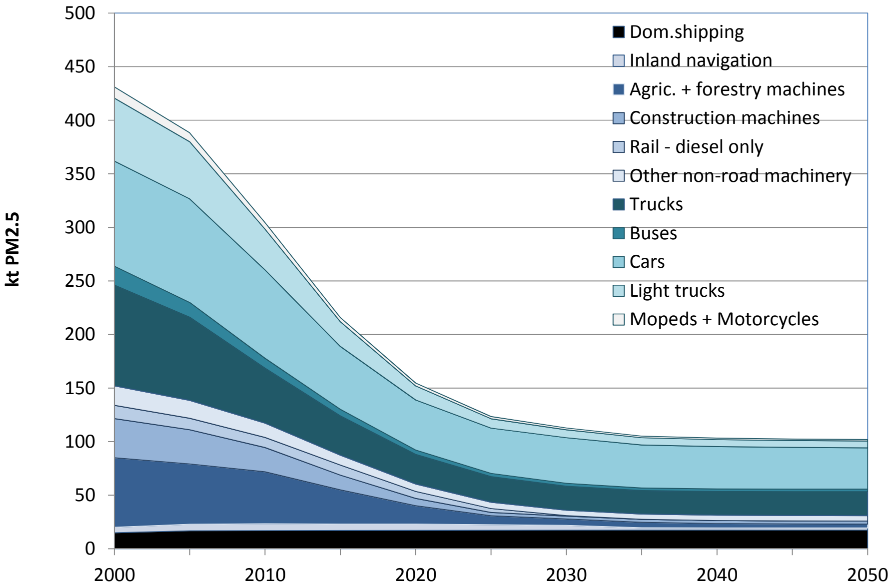

Figure 4.2: Development of PM2.5 emissions from mobile sources in EU27 for the baseline scenario

Table 4-2: Emissions of PM_{10} and $PM_{2.5}$ by road and non-road vehicle category in the TSAP-2012 baseline and MTFR scenarios, changes relative to the year 2005, and share of mobile sources in total emissions in EU27 at selected years.

		TSAP-2012 baseline			*MTFR scenario*		
	2005	2020	2030	2050	2020	2030	2050
Dom.shipping	17	17	17	17	17	17	17
Inland navigation	6.0	5.8	4.4	2.0	5.7	4.0	1.1
Agric. + forestry machines	56	17	6.0	3.6	18	4.9	1.5
Construction machines	32	6.9	2.7	2.9	7.1	1.7	1.5
Rail - diesel only	11	6.5	0.5	0.0	6.9	0.5	0.0
Other non-road machinery	17	7.0	5.0	5.0	7.5	5.3	5.3
Heavy trucks - diesel	63	9	1.6	0.5	8.5	1.7	0.6
Cars and light trucks - gasoline	3	2	1.7	1.7	1.8	1.7	1.7
Cars and light trucks - diesel	118	23	6.9	3.9	22.4	5.2	1.9
Mopeds + motorcycles	8	2	1.3	0.8	2.4	1.3	0.8
Buses + all other	12	2	0.7	0.4	2.2	0.7	0.4
Tyre, brake, abrasion: $PM_{10}/PM_{2.5}$	110/44	140/57	160/65	157/64	140/57	133/56	114/50
Sum Non-road+Road: $PM_{10}/PM_{2.5}$	454/388	238/155	207/112	195/102	237/154	177/100	146/82
Change vs. 2005: $PM_{10}/PM_{2.5}$	0%	-48%/ -60%	-55%/ -71%	-57%/ -74%	-48%/ -60%	-62%/ -74%	-68%/ -79%
Non-road in Total all sectors	6%/8%	3%/5%	2%/3%	2%/3%	5%/8%	3%/6%	3%/5%
Road in Total all sectors	12%/14%	9%/7%	10%/7%	10%/7%	15%/12%	16%/13%	16%/11%

4.3.1 Road transport

Road vehicles contributed 12% to total PM_{10} and 14% to $PM_{2.5}$ emissions in the EU-27 in 2005. Diesel vehicles were the major source; heavy trucks, light trucks and diesel cars are the vehicle categories with the highest shares in emissions, followed by buses. Emissions from gasoline cars, mopeds and motorcycles account for less than 5%. In 2005, tyre, brake and gear wear, and road abrasion contributed more than one third to PM_{10} and about 20% to $PM_{2.5}$ emissions from road vehicles. These particles are not related to the combustion process, but originate from mechanical processes.

Baseline

Forthcoming emission controls and notably the increased penetration of (diesel) particle filters are expected to reduce road vehicle exhaust emissions by 80% and 94% until 2020 and 2030, respectively, and even further until 2050. The phase-out of two-stroke mopeds and scooters will lead to similar reductions for this vehicle category. Mass emissions from gasoline cars are expected to remain at very low levels throughout the period.

Non-exhaust emissions are not regulated, and not affected by exhaust emission control systems. Their amount is projected to grow by almost 30% and 50% until 2020 and 2030, respectively in the absence of dedicated control measures. Thus, they become the dominant source of PM_{10} and $PM_{2.5}$ from road vehicles in the baseline case.

Maximum technically feasible reductions

Introduction of the hypothetical additional emission control case could further reduce PM emissions from vehicles, especially for light duty diesel vehicles. With the assumed efficiencies, it could reduce PM emissions by 24% and 50% below the baseline levels in 2030 and 2050. However, total mass emissions of PM_{10} will be dominated by up to 90% by non-exhaust emissions from road abrasion, tyre and brake wear. Better brake pads and discs, as well as reformulated rubber mixtures for tyres might reduce wear by 30% and 50% in 2030 and 2050, respectively. This would translate to about 7 kt less $PM_{2.5}$ mass emissions, roughly 10% and 14% in 2030 and 2050.

4.3.2 Non-road sources

Non-road vehicles emitted about 8% of total $PM_{2.5}$ in the EU-27 in 2005. Almost two thirds emerge from mobile machines used in agriculture, forestry, for construction and in industry. Ships, diesel locomotives and small two-stroke machines like chain saws, lawn mowers and snow scooters contributed about equally to the remainder.

Baseline

Emissions from these diesel powered machines are expected to decline by 70% to 80% until 2020 with the gradual implementation of Stages IIIB and IV for mobile machines. The turnover and hence the penetration of new emission controls is much slower for ships; therefore their emissions do not decrease until 2020, and will fall by 5% afterwards. Thus, domestic shipping becomes the single biggest source category among non-road vehicles. Emissions from diesel locomotives and railcars are projected to decline by 40% until 2020. After this period, the baseline scenario assumes a phase-out of diesel traction, which would result in a fall of emissions to only 5% of the 2005 level.

In general, emissions from mobile sources level off from 2035 onwards as all currently adopted emission controls will by then have fully penetrated the fleet and no further controls are assumed.

Maximum technically feasible reductions

Measures are practically available to further reduce PM emissions from diesel powered mobile machines in agriculture and forestry, as well as from industry and the construction sector. This could reduce their emissions by 20% in 2020, 40% by 2030, 60% in 2040 and 50% in 2050 below baseline. However, these sectors are projected to contribute only 25% to total non-road emissions in 2030 in the baseline scenario, while vessels contribute 60%. Thus, without effective controls on ships, total non-road emissions cannot be reduced much.

4.4 Emissions of black carbon (BC)

BC emissions from mobile sources are projected to decline strongly under the baseline scenario (Figure 4.3).

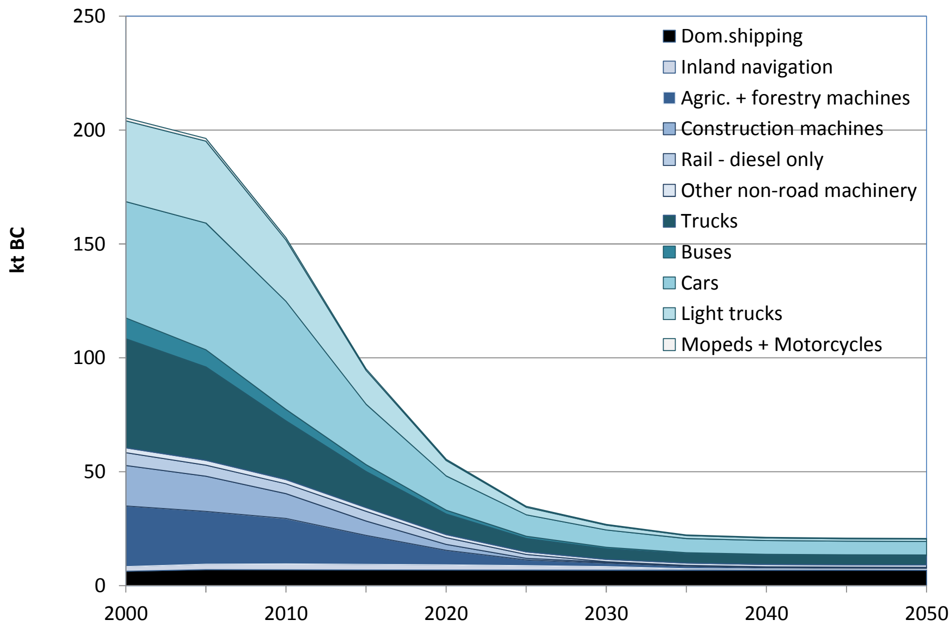

Figure 4.3: Development of BC emissions from mobile sources in EU27 for the baseline scenario

Table 4-3: Baseline emissions of BC by vehicle category for road and non-road sources, trends relative to the year 2005 and share of mobile sources in total emissions in the EU-27 for selected years

BC	*kt* 2005	*kt* 2020	*kt* 2030	*kt* 2050	*2005=100%* 2020	2030	2050
Dom.shipping	7.0	6.8	6.8	6.8	97%	96%	96%
Inland navigation	2.4	2.3	1.6	0.4	95%	66%	17%
Agric. + forestry machines	23.2	6.4	1.6	0.4	28%	7%	2%
Construction machines	15.5	2.6	0.4	0.4	17%	3%	3%
Rail – diesel traction only	4.9	3.0	0.2	0.0	61%	4%	0%
Other non-road machinery	2.1	1.3	1.0	1.0	63%	48%	48%
Heavy trucks - diesel	38.5	5.6	0.9	0.1	15%	2%	0%
Cars and light trucks - gasoline	0.7	0.3	0.3	0.3	43%	39%	38%
Cars and light trucks - diesel	86.6	16.2	3.2	0.7	19%	4%	1%
Mopeds + motorcycles	1.1	0.5	0.3	0.2	40%	25%	17%
Buses + all other	7.3	1.4	0.3	0.1	19%	4%	1%
Tyre, brake, abrasion	7.2	9.2	10.4	10.3	128%	146%	145%
Sum Non-road + Road	196	56	27	21	28%	14%	11%
Non-road in Total all sectors	15%	11%	7%	7%			
Road in Total all sectors	38%	16%	10%	8%			

4.4.1 Road transport

Road vehicles contributed almost 40% to total emissions of BC in the EU-27 in the year 2005. Emissions from gasoline vehicles accounted for about 2%, shared between exhaust and non-exhaust; the rest was emitted by trucks, diesel cars and light trucks, and buses. In 2005, tyre, brake and gear wear and road abrasion contributed about 5% to the total.

Baseline

Progressing implementation of emission controls, especially the increasing penetration of (diesel) particle filters, are expected to reduce road vehicle exhaust emissions of BC by more than 80% and 95% until 2020 and 2030, respectively, and even further until 2050. Emissions from gasoline cars are expected to remain at very low levels throughout the period. However, no effective controls are in place for non-exhaust emissions of BC. Thus, their evolution would follow the increase in traffic volumes, and thereby grow by almost 30% and 50% until 2020 and 2030, respectively. These trends would reduce the share of road transport emissions in BC to 16% in 2020 and 10% in 2030, and make non-exhaust emissions the dominant source of BC from road vehicles. However, it should be noted that non-exhaust emissions (of black carbon) are usually of larger size (>2.5 µm) and thus have different health and climate impacts than small particles.

4.4.2 Non-road sources

Non-road mobile sources emitted about 15% of total BC emissions in the EU-27 in 2005. More than two thirds originated from mobile machinery in agriculture, forestry, construction and industry. Ships, diesel locomotives and small two-stroke machines like chain saws, lawn mowers and snow scooters contributed the remaining 17%, 10% and 5%.

Emissions from diesel powered machines are expected to decline by more than 70% and 80% until 2020, following the gradual implementation of Stages IIIB and IV for mobile machinery. The turnover and hence the penetration of new emission controls is much slower for ships; therefore their emissions decrease by 3% and 11% until 2020 and 2030 in the baseline. Ships become the single biggest source category among non-road mobile sources. Emissions from diesel locomotives and railcars are projected to decline by 40% until 2020. After this period, the baseline assumes a phase-out of diesel traction.

In general, emissions from mobile sources level off from 2035 onwards as all currently adopted emission controls will by then have fully penetrated the fleet and no further controls are assumed.

4.5 Emissions of organic carbon (OC)

OC emissions from mobile sources are projected to decline strongly under the baseline scenario (Figure 4.4).

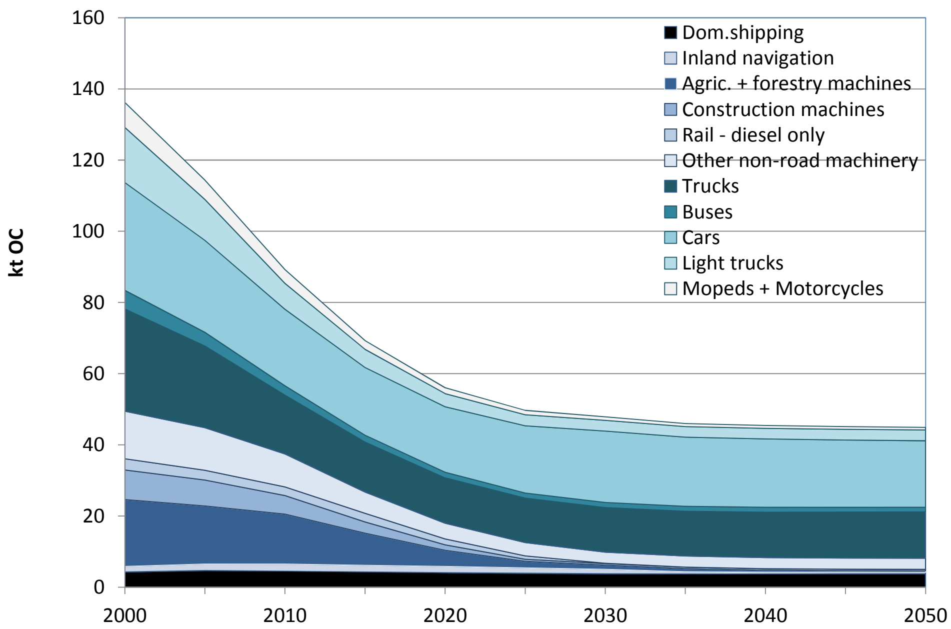

Figure 4.4: Development of OC emissions from mobile sources in the EU27 for the baseline scenario

Table 4-4: Emissions of OC by vehicle category for road and non-road sources, trends relative to the year 2005 and share of mobile sources in total emissions in EU27 at selected years according to the Baseline scenario.

OC	*kt* 2005	*kt* 2020	*kt* 2030	*kt* 2050	*2005=100%* 2020	2030	2050
Dom. shipping	4.7	4.1	3.8	3.8	87%	80%	80%
Inland navigation	1.8	1.8	1.3	0.4	96%	69%	24%
Agric. + forestry machines	16.3	4.5	1.2	0.4	28%	7%	2%
Construction machines	7.3	1.5	0.4	0.5	21%	6%	6%
Rail – diesel traction only	2.7	1.7	0.1	0.0	61%	4%	0%
Other non-road machinery	11.9	4.4	3.1	3.1	37%	26%	26%
Heavy trucks – diesel	14.7	1.6	0.3	0.2	11%	2%	1%
Cars and light trucks - gasoline	1.5	0.7	0.6	0.6	44%	40%	39%
Cars and light trucks - diesel	21.4	3.5	1.5	1.1	16%	7%	5%
Mopeds + motorcycles	5.3	1.4	0.7	0.5	27%	14%	9%
Buses + all other	3.0	0.5	0.2	0.2	16%	7%	6%
Tyre, brake, abrasion	23.7	30.4	34.7	34.3	128%	146%	144%
Sum Non-road + Road	114	56	48	45	49%	42%	39%
Non-road in Total all sectors	10%	5%	4%	3%			
Road in Total all sectors	16%	12%	14%	15%			

4.5.1 Road transport

Road vehicles contributed about 16% to total emissions of OC in EU27 in the year 2005. Exhaust emissions from gasoline cars, mopeds and motorcycles account for 11%, the rest came from trucks, diesel cars and light trucks, and buses. For 2005, it is estimated that tyre, brake and gear wear and road abrasion contributed about one third of the total OC, although not necessarily to the PM2.5 fraction of OC.

Baseline

Forthcoming emission controls and especially the increasing penetration of (diesel) particle filters are expected to reduce road vehicle exhaust emissions of OC by more than 85% and 95% until 2020 and 2030, respectively, and even further until 2050. OC emissions from gasoline cars are expected to remain at very low levels throughout the period, and two-stroke mopeds and scooters will be phased-out or cleaned. The share of road transport emissions will remain at 12 - 14%.

Non-exhaust emissions are projected to grow by almost 30% and 50% until 2020 and 2030, respectively, in the absence of dedicated control measures. Thus, in terms of mass they would become the dominant source of OC from road vehicles.

4.5.2 Non-road sources

Non-road mobile machinery emitted about 10% of total OC emissions in the EU-27 in the year 2005. More than half is emitted by mobile machinery in the agriculture, forestry, construction and industry sectors. Small two-stroke machines like chain saws, lawn mowers and snow scooters contribute about one quarter, ships and diesel locomotives the remaining 15% and 7%, respectively.

Emissions from these diesel powered machines are expected to decline by more than 70% and 90% until 2020 and 2030, respectively, following the gradual implementation of Stages IIIB and IV for mobile machines. The turnover and hence the penetration of new emission controls is much slower for ships; therefore their emissions decrease by 10% and 23% until 2020 and 2030. Ships become the single biggest source category among non-road vehicles. Reduction rates for small machinery are 60% and 75% until 2020 and 2030, respectively, as little emission controls are applied. This makes this group the second most important source category. Emissions from diesel locomotives and railcars are projected to decline by 40% until 2020. The baseline scenario assumes phase-out of diesel traction after 2030.

In general, OC emissions from mobile sources level off from 2035 onwards as all currently adopted emission controls will by then have fully penetrated the fleet and no further controls are assumed.

4.6 Emissions of volatile organic compounds (VOC)

VOC emissions from mobile sources are projected to decline strongly under the baseline scenario (Figure 4.5).

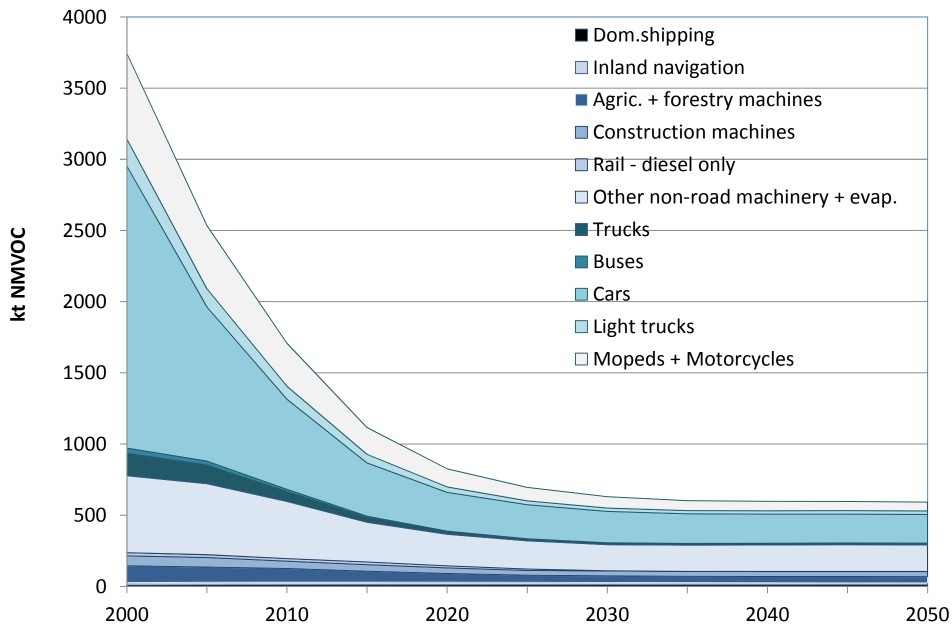

Figure 4.5: Development of VOC emissions from mobile sources in the EU27 for the baseline scenario

Table 4-5: Emissions of NMVOC by vehicle category for road and non-road sources, trends relative to the year 2005 and share of mobile sources in total emissions in EU27 at selected years (baseline scenario).

NMVOC	*kt* 2005	*kt* 2020	*Kt* 2030	*kt* 2050	*2005=100%* 2020	2030	2050
Dom. shipping	10	11	11	11	107%	110%	110%
Inland navigation	19	19	17	14	101%	89%	73%
Agric. + forestry machines	107	61	47	44	57%	44%	41%
Construction machines	67	39	34	36	58%	51%	54%
Rail - diesel only	20	15	2	0	73%	8%	2%
Other non-road machinery + evap.	499	222	183	186	45%	37%	37%
Heavy trucks - diesel	128	16	5	4	12%	4%	3%
Cars and light trucks - gasoline	1052	239	185	174	23%	18%	17%
Cars and light trucks - diesel	95	46	42	40	49%	44%	42%
Mopeds + motorcycles	444	127	80	62	29%	18%	14%
Buses + all other	95	32	25	21	33%	26%	22%
Evaporative	391	71	53	50	18%	13%	13%
Sum Non-road + Road	2927	897	683	642	31%	23%	22%
Non-road in Total all sectors	8%	6%	5%	5%			
Road in Total all sectors	23%	9%	7%	6%			

4.6.1 Road transport

In 2005, road transport contributed about 23% to total VOC emissions in the EU-27. Gasoline cars, mopeds and motorcycles are the main emitters. Evaporation from vehicles' tanks and during fuelling has a share of 17% of road vehicle emissions, i.e., more than emissions from all diesel vehicles together, which contribute 15%.

Emissions from gasoline cars are projected to decrease by 77% and 82% until 2020 and 2030, respectively, with the introduction of further emission control stages. A reduction by 70% and 80% is expected for motorcycles, enhanced by the phase-out of two-stroke mopeds and scooters. Evaporative emissions will decline even stronger with tighter controls and sealing technologies. Total VOC emissions from road transport will fall by 75% and 80%, and contribute 7% and 6% to totals in 2020 and 2030, respectively.

4.6.2 Non-road sources

Non-road mobile machinery emitted about 8% of total VOC emissions in the EU-27 in 2005. Small two-stroke machines like chain saws, lawn mowers and snow scooters contribute more than twice as much than all other non-road sources together. Mobile machines used in agriculture, forestry, in construction and industry account for another quarter of non-road emissions.

Reduction rates for small machinery are 55% and 63% until 2020 and 2030, respectively. This category will remain the single most important source for VOC emissions. Emissions from agricultural and construction machines are expected to decline by 40% and 50% until 2020 and 2030, respectively, following the gradual implementation of Stages IIIB and IV for mobile machines. Emissions from ships remain at the current level and emissions from diesel locomotives and railcars will diminish with their projected phase-out between 2020 and 2030.

5 Sensitivity analyses

As discussed above, the future development of emissions depends on a number of assumptions, *inter alia* about the demand for total transport services and transport modes, the fleet turnover, how these factors will be influenced by policies and behavioural changes, and the effectiveness of new emission control legislation.

To highlight the potential implications of such uncertainties on the overall development of emissions, this report has developed the following sensitivity cases:

- A '**decarbonisation**' scenario, in which the energy and transport systems are transformed in such a way that transport-related CO_2 emissions are reduced by about 60% by 2050 compared to 1990, with emissions from all sectors decreasing by 80% (EC 2011). Inter alia, the scenario includes a possible pathway of an electrification of the European transport system.
- A '**maximum control efforts'** (MCE) scenario that explores to what extent emissions from mobile sources could be reduced through a combination of stringent decarbonisation strategies, including behavioural changes, and the full application of the available end-of-pipe emission control measures.
- Several sensitivity scenarios explore the implications of different timing and stringencies of **real-driving Euro 6 emissions** from light duty diesel vehicles on total NO_x emissions.
- Finally, a retrospective analysis explores the hypothetical evolution of NO_x emissions from light duty diesel vehicles if real-world emissions factors would have decreased to the same extents as the limit values.

5.1 A decarbonisation scenario

For the TSAP-2012 baseline analysis, a sensitivity case has been developed that explores the implications of a stringent decarbonisation strategy on the emissions of air pollutants in the EU-27. It employs the 'Global Action with Effective and Widely accepted Technology' scenario that has been developed with the PRIMES model for the communication of the European Commission on a 'A roadmap for moving to a competitive low carbon economy in 2050' (EC 2011a). The scenario examines the transformation of the European energy and transport systems in response to a stringent carbon constraint that would reduce greenhouse gas emissions in the EU by 80% in 2050. The scenario assumes a policy environment that enables all mayor low carbon technologies, such as energy efficiency and renewables, carbon capture and storage (CCS), nuclear and electrification of transport.

For the transport sector, this scenario would result in 60% less CO_2 emissions in 2050 compared to 1990, and drastically decrease the dependence of transport on oil (EC 2011b). It assumes a sharp increase of the fuel efficiency of light and heavy duty vehicles, a strong shift from gasoline and diesel powered cars to electric cars from 2020 onwards without much change in travel volume, a significantly lower growth in road freight transport volumes, and a substantial uptake of 2nd generation biofuels. Modal shifts do not play a significant role in this scenario. The expected additional demand for electricity is accounted for in the supply structure of power generation through the feedback loops in the PRIMES model.

In the decarbonisation scenario, advanced hybrid, plug-in hybrid and electric vehicles are assumed to be phased in from 2020 onwards. This may result from a combination of improvements in battery storage capacity, durability and charging time, cost reductions, changing customer preferences, positive legislative discrimination (environmental zones or right-of-way), subsidies and financial incentives, and higher oil prices. These vehicles substitute conventional vehicles, and they will have lower emissions particularly under urban driving conditions. This can be beneficial for compliance with NO_2 and PM_{10}/$PM_{2.5}$ air quality targets.

For air pollutant emissions, any shift of transport from vehicles with internal combustion engines to electric vehicles virtually eliminates exhaust emissions of all pollutants. In fact, emissions are shifted to the place of power generation. Usually they are lower because centralised production has stricter emission limits, uses a significant share of non-fossil primary energy, and because final energy demand of electric vehicles is lower. Furthermore, impacts on air quality and health will change as pollutant emissions are shifted from urban areas to more remote locations. Hence, emissions from passenger cars are bound to decrease with the exception of non-exhaust wear and abrasion. Details of this alternative demand projection for the different transport modes are given in Table 5-1.

Table 5-1: Fuel consumption by vehicle category for road and non-road sources, changes relative to the year 2005 and relative to the respective emission in the baseline, and share of mobile sources in total emissions in the EU-27 for selected years for the decarbonisation scenario.

Fuel consumption		*Decarbonisation Scenario*			*Change vs. Baseline Scenario*		
	PJ	PJ	PJ	PJ	PJ	PJ	PJ
	2005	2020	2030	2050	2020	2030	2050
Dom. shipping	286	309	320	320	0%	0%	0%
Inland navigation	86	88	88	88	-71%	-73%	-73%
Agric. + forestry machines	546	544	511	133	-1%	-2%	-74%
Construction machines	398	370	378	164	3%	4%	-59%
Rail - diesel traction	129	121	21	4	4%	22%	-6%
Rail - electric traction	266	309	371	341	2%	10%	-4%
Dom. aircraft + other non-road	2208	2835	2871	2477	2%	0%	-19%
Heavy trucks - diesel	3005	3463	3223	1596	0%	-1%	-53%
Cars and light trucks - gasoline	4634	3867	3049	1507	-6%	-23%	-62%
Cars and light trucks - diesel	3967	4402	4197	1816	-2%	-3%	-57%
Cars and light trucks - electric	1	159	878	2743	20270%	35850%	7591%
Mopeds + Motorcycles	162	141	127	59	-5%	-23%	-65%
Buses + all other	704	824	814	682	1%	5%	1%
Sum Non-Road + Road	16390	17432	16848	11928	-1%	-1%	-30%
Non-road in Total all sectors	5%	6%	6%	6%			
Road in Total all sectors	16%	18%	17%	14%			

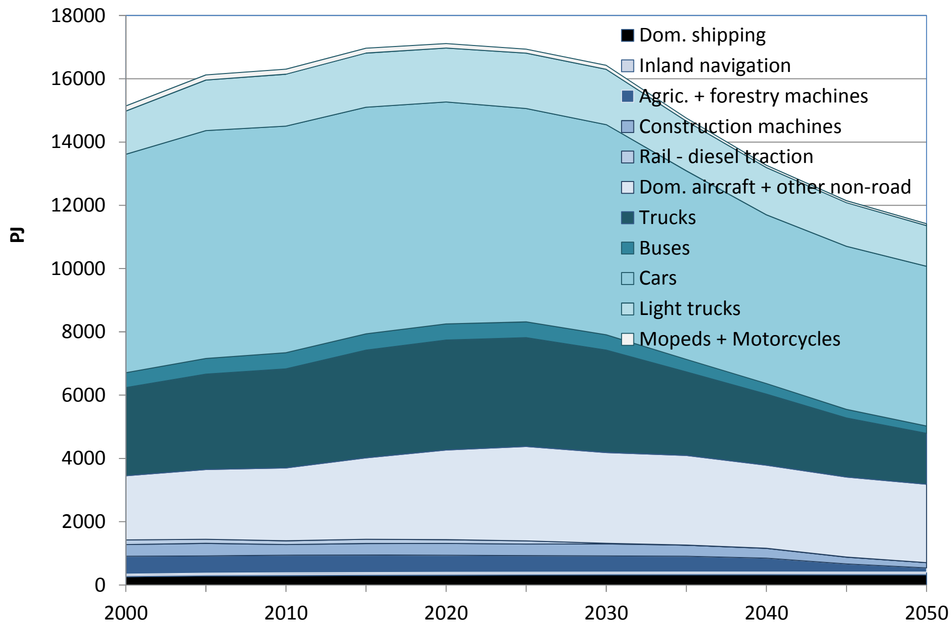

Figure 5.1: Development of fuel consumption from mobile sources in the EU-27 in the decarbonisation scenario

Road transport

The decarbonisation scenario differs from the baseline essentially in the fuel efficiency of vehicles and in the number of electric passenger cars. All these changes materialise from 2030 onwards.

Electric cars are assumed to account for 2% of the final energy consumption of cars in 2020, for 10% in 2030, and for 45% in 2050. They take over mileage shares from conventional (though improved) gasoline vehicles already from 2020 onwards, and later from diesel and hybrid cars whose consumption is consequently reduced substantially after 2030. Fuel consumption by trucks is the same as in the baseline up to 2030, but then declines drastically. By 2050, trucks are supposed to consume only half the fuel compared to the baseline. Thereby, total final energy demand from road vehicles is about equal to the baseline projection until 2030, but 30% below the baseline in 2050, which means that it is also one third below the 2005 consumption by road vehicles.

Non-road transport

Fuel consumption of non-road mobile sources is essentially the same as in the baseline scenario until 2030. Only consumption of railways is 10% higher due to a dedicated quicker expansion of electric traction. From 2030 onwards, consumption of diesel mobile machines reduces strongly due to significant improvements in the engine efficiency (e.g., for heavy duty trucks), and because of more efficient logistics. Consumption from domestic air travel decreases from 2030 onwards to 20% below the baseline level in 2050. Energy consumption of railways will reach baseline levels in 2050.

Overall, fuel consumption of non-road sources increases until 2025 by more than 20% over the 2005 level, and then continuously decreases to 10% below the 2005 level.

5.2 A Maximum Control Efforts (MCE) scenario

The MCE scenario assumes the same development of the energy and transport systems as the decarbonisation scenario, combined with maximum application of end-of-pipe emission control measures. These include for light and heavy-duty vehicles the hypothetical additional control stage beyond EURO 6/VI that are described above, as well as a Stage V for non-road mobile machinery following the same characteristics and application rates as in the MTFR scenario (Maximum Technically Feasible Reduction).

Mineral and biogenic fuels need to satisfy the same key specifications relevant for the proper functioning and combustion of modern engines and after-treatment systems. Therefore, it is assumed that emission factors remain the same regardless of fossil or regenerative fuel, pure or mixed.

5.3 Emissions of the MTFR and MCE scenarios

The sensitivity analysis focuses on emissions of NO_x and PM, i.e., on the pollutants that are currently of largest concern for the transport sector. Emissions of other pollutants are provided in detail on the website http://gains.iiasa.ac.at. The analysis focuses on the year 2030, when changes show their full impacts.

5.3.1 NO_x emissions

The evolution of NO_x emissions from mobile sources in the decarbonisation scenario is shown in Figure 5.2.

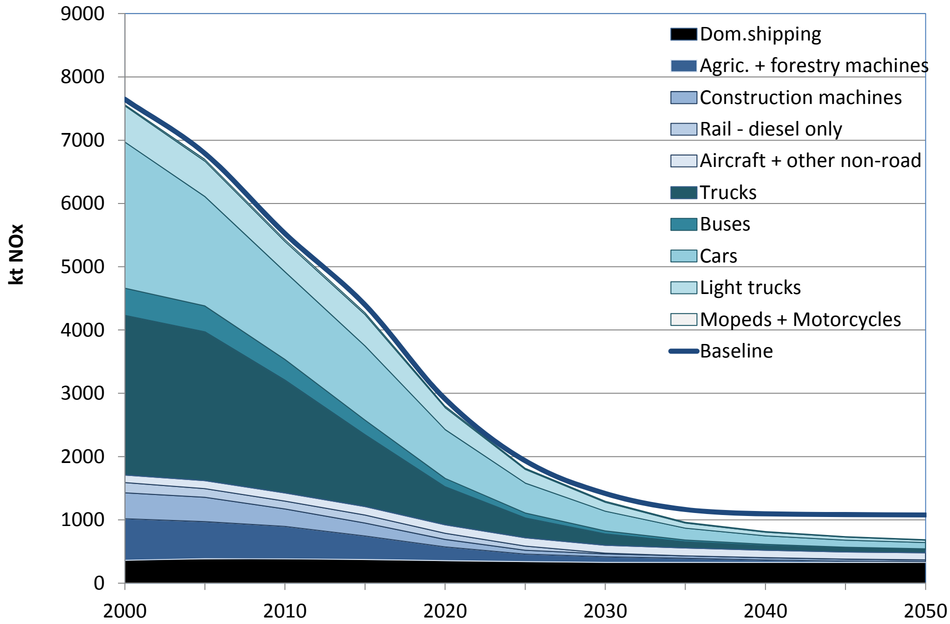

Figure 5.2: Development of NO_x emissions from mobile sources in the EU27 for the decarbonisation scenario.

Table 5-2: NO_x emissions by vehicle category for road and non-road sources, changes relative to the year 2005 and relative to the respective emissions in the baseline and the MTFR scenarios, and share of mobile sources in total emissions of EU27, at selected years comparing the decarbonisation and the MCE scenarios.

NO_x	kt 2005	*Decarbonisation Scenario* kt 2020	kt 2030	kt 2050	*MCE Scenario* kt 2020	kt 2030	kt 2050
Dom.shipping	386	354	327	327	354	327	327
Inland navigation	96	100	86	65	97	73	23
Agric. + forestry machines	585	219	89	12	218	78	8
Construction machines	385	116	47	26	115	38	21
Rail - diesel only	137	98	11	2	97	9	1
Aircraft + other non-road	127	134	125	112	134	125	112
Heavy trucks - diesel	2349	600	178	50	596	164	41
Cars and light trucks - gasoline	929	126	67	31	126	67	31
Cars and light trucks - diesel	1289	976	376	101	843	259	63
Mopeds + motorcycles	26	21	16	6	21	16	6
Buses + all other	482	150	60	20	149	53	16
Sum Non-road + Road	6791	2896	1380	751	2751	1208	649
Change vs. 2005	0%	-57%	-80%	-89%	-59%	-82%	-90%
Change vs. Baseline / MTFR	0%	0%	-3%	-30%	0%	-3%	-27%
Non-road in Total all sectors	15%	19%	19%	22%	23%	25%	30%
Road in Total all sectors	44%	34%	19%	8%	39%	22%	10%

Road transport

The decarbonisation scenario

For 2020, there are no major differences in NO_x emissions between the decarbonisation and the baseline scenario for any vehicle categories. By 2030, emissions from gasoline cars and motorcycles are about 20% lower, as electric vehicles enter the market. From 2030 onwards, the massive replacement of conventional cars and the significant reduction in fuel consumption of heavy duty vehicles lead to 86% lower NO_x emissions from road transport (Table 5-2). By 2050 then, emissions would only be 4% of the 2005 level. The biggest absolute reduction over the baseline scenario, about 130 kt less NO_x in 2050, results from the replacement of diesel cars by electric cars. The replacement of gasoline cars and reductions from heavy duty vehicles contribute another 50 kt and 55 kt each.

The MCE scenario

The additional emissions controls assumed in the MCE scenario affect primarily diesel cars and light trucks, and to a much smaller extent heavy duty vehicles. These measures would reduce emissions from diesel light duty vehicles by 80% in 2030 (Table 5-2).

Afterwards, the additional measures will lead to further reductions, although applied to fewer vehicles, as conventional cars will be replaced by electric cars. NO_x emissions from diesel light duty vehicles could be another 40 kt lower by 2050, bringing total NO_x emissions from road transport down to only 3% of the 2005 level.

Non-road sources

The decarbonisation scenario

NO_x emissions from non-road vehicles develop in the decarbonisation scenario until 2030 essentially as in the baseline. Beyond that, strong reductions in activity levels of diesel powered mobile machines translate to similar reductions in emissions. However, emissions from vessels, the biggest source category, may not be affected as no change in activity is assumed. Due to an increase in rail activity, there are higher emissions from locomotives, yet at altogether low level. Overall, by 2050 emissions could be 60kt or 11% lower than in the baseline scenario.

The MCE scenario

In the MCE scenario, additional NO_x controls (Stage V) are assumed for mobile machinery. However, as emissions are already quite low, additional reductions will be small. Ships and aircraft remain the most important source categories of non-road transport. Overall NO_x emissions from non-road sources could be 40 kt or 7% lower in 2050 than in the MTFR scenario, at about 30% of the 2005 level.

5.3.2 PM2.5 emissions

The evolution of PM2.5 emissions from mobile sources in the decarbonisation scenario is shown in Figure 5.3.

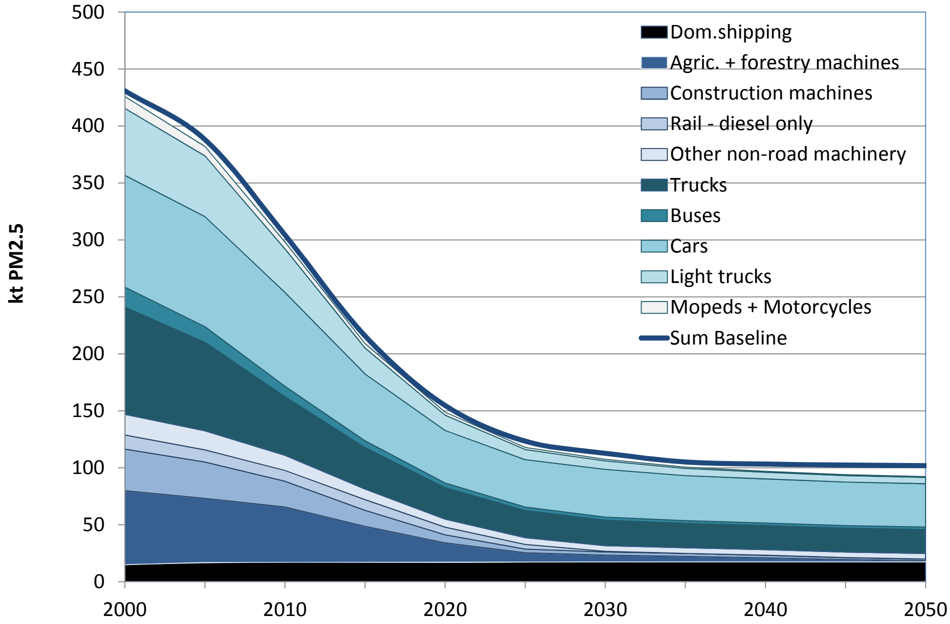

Figure 5.3: Development of PM2.5 emissions from mobile sources in EU27 for the decarbonisation scenario.

Table 5-3: PM2.5 emissions by vehicle category for road and non-road sources, changes relative to the year 2005 and relative to the respective emission in the baseline and the MTFR scenarios, and shares of mobile sources in total emissions in the EU-27 for selected years, for the decarbonisation and MCE scenarios.

$PM_{2.5}$		*Decarbonisation scenario*			*MCE scenario*		
	kt	kt	kt	kt	kt	kt	kt
	2005	2020	2030	2050	2020	2030	2050
Dom.shipping	17	17	17	17	17	17	17
Inland navigation	6.0	5.8	4.4	2.0	5.7	4.0	1.1
Agric. + forestry machines	56	17	5.9	1.1	17	4.6	0.5
Construction machines	32	7	2.8	1.4	7	1.7	0.9
Rail - diesel only	11	7	0.6	0.0	7	0.6	0.0
Other non-road machinery	17	7	4.9	4.7	7	4.9	4.7
Heavy trucks – diesel	63	9	1.6	0.2	9	1.7	0.3
Cars and light trucks - gasoline	3	2	1.3	0.7	2	1.3	0.7
Cars and light trucks - diesel	118	22	6.8	1.7	22	5.2	0.8
Mopeds + motorcycles	8	2	1.0	0.3	2	1.0	0.3
Buses + all other	12	2	0.6	0.2	2	0.6	0.2
Tyre, brake, abrasion	44	57	65	65	57	56	51
Sum Non-road + Road	388	155	112	94	154	99	78
Change vs. 2005	0%	-60%	-71%	-76%	-60%	-74%	-80%
Change vs. Baseline / MTFR	0%	0%	-1%	-7%	0%	-1%	-11%
Non-road in Total all sectors	8%	5%	4%	3%	11%	7%	6%
Road in Total all sectors	14%	8%	7%	7%	17%	16%	16%

Road transport

The decarbonisation scenario

Due to the assumptions taken, differences to the baseline can only emerge after 2030. However, PM2.5 emissions will by then already have decreased by 70% (Figure 5.3). The further reduction in activity, notably from diesel light and heavy duty vehicles, will cut remaining emissions by another 50% to 60% until 2050. However, this change will be less relevant as total emissions will be dominated by road abrasion (37 kt in 2050), brake wear (22 kt in 2050), and tyre wear (6 kt in 2050). Hence, in the absence of legislation addressing any of these non-combustion related sources, no significant further progress in reducing PM2.5 emissions will be made. Total road transport emissions are projected to be 5% lower in the decarbonisation scenario compared to the baseline in 2050 (Table 5-3).

The MCE scenario

The MCE scenario assumes additional exhaust emission controls for road vehicles. However, as explained above, they apply to an already low number. Yet, new materials for tyres and brake pads and discs could contribute to lower road transport PM2.5 emissions by 13% and 22% in 2030 and 2050, respectively. Nonetheless, road abrasion remains by far the dominant source.

Non-road sources

The decarbonisation scenario

Changes in PM emissions are limited as no further measures for domestic shipping are assumed in this scenario. By 2050, lower activity levels of diesel powered machines in agriculture and construction may lead to a reduction of 14% below the baseline level.

The MCE scenario

No relevant extra controls are assumed in the MCE scenario for these sources, hence it develops almost identical to the decarbonisation scenario.

5.4 Sensitivity of NO_x emissions to EURO 6 real-driving emissions

One of the most important uncertainties about the future NO_x development relates to emissions from light duty diesel vehicles under real-world driving conditions. Both, the TSAP-2012 baseline and the decarbonisation scenarios assume a stepwise decrease of real-driving emissions with the introduction of the EURO 6 emission standard. Second generation EURO 6.b (from 2017 onwards) light duty diesel vehicles are assumed to emit only 120 mg NO_x/km at average real-world driving; the limit value over the type approval cycle is 80 mg/km. Given that EURO 5 vehicles are measured at almost 870 mg NO_x/km under real-world driving (Hausberger 2010), the assumed reduction requires a step change in technology and notably the test procedure. First measurements on premium-class vehicles have shown that it is technically feasible to achieve the low value with SCR technology under real-world driving (Demuynck et al. 2012; Hausberger 2012).

As this development is however not certain, sensitivity cases explore how much total NO_x emissions would be affected by different real-driving emissions from light duty diesel vehicles. To span a range of possible developments the following cases are considered:

- The baseline scenario: “Stepwise lower”: A stepwise reduction of real-driving emissions is assumed, such that a first generation of EURO 6 vehicles (EURO 6.a) delivers a reduction over EURO 5 proportional to the reduction in emission limit values by 2014 (2015), i.e., about 380 mg/km. The second generation vehicles (EURO 6.b) are assumed to emit on average 1.5 times the limit value under real-world driving from 2017 (2018) onwards, i.e., 120 mg/km. This reduction may result from the introduction of real-drive emission controls, e.g., by on-board PEMS or random cycle testing. Such a scenario could be considered as the most realistic option based on recent developments.
- “Legislation”: Average real-driving NO_x emissions of EURO 6 diesel LDV are assumed equal to the emission limit value of 80 mg/km from 2015 onwards. With current knowledge, this seems a low emission scenario.
- “Delayed steps”: As in the “Stepwise lower” case, but second generation vehicles (EURO 6.b) are assumed to be available only from 2020 onwards due to a delayed introduction of real-drive emission controls.
- “Proportional”: EURO 6 vehicles are introduced in 2015, but they only deliver emission reductions proportional to the ratio of the emission limits over EURO 5, i.e., about 380 mg/km. This is the ‘default’ approach used by COPERT 4 and the Handbook Emission Factors.
- “EURO 6 = EURO 4”: It is assumed that real-driving emissions from EURO 6 diesel LDVs are only 30% lower than those of the previous generation and thus similar to those of EURO 4 vehicles. This pessimistic scenario would correspond to historic experience that new emission limit values did not result in reduced real-driving emissions. It is thus a scenario where the legislation fails.

As shown earlier, NO_x emissions from all road vehicles in the EU- 27 are projected to decrease further from about 5000 kt in the year 2005. Under baseline assumptions, they are expected to decline to about 1900 kt in 2020 and 730 kt in the year 2030 (Figure 5.4 – left panel). However, this decline is driven by decreasing unit emissions from gasoline cars and heavy duty vehicles, while emissions from light duty diesel vehicles are expected to increase at least until the year 2015. Light duty diesel vehicles contributed about one quarter to NO_x from all road vehicles in the EU-27 in 2005. By 2015, their share in emissions is projected to grow to 45%, when they will emit 1400 kt. By then, EURO 6 vehicles will enter the market and under baseline assumptions emissions from light duty diesel vehicles will gradually decrease to 1000 kt and 380 kt in year 2020 and 2030 respectively (Figure 5.4 – right panel).

If real-driving emissions would be as low as the nominal limit value from 2015 onwards (scenario "Legislation"), total NO_x emissions from road vehicles would be 180 kt and 140 kt lower in 2020 and 2030, respectively, or by 10% and 18% lower than in the baseline.

A potential delay in the timing of the EURO 6.b emission step to the year 2020 would result in 120 kt and 95 kt higher NO_x emissions in 2020 and 2030, or 6% and 13% more than in the baseline scenario, respectively.

If Euro 6 vehicles would only deliver a proportional reduction on real-driving, then NO_x emissions from light duty diesel vehicles would be 130 kt higher in the year 2020; in the year 2030 they would be more than twice as high compared to the baseline projection. In consequence, NOx emission from all road vehicles would be higher by 7% and 60% years 2020 and 2030 respectively, though still at a much reduced level compared to the year 2005.

If EURO 6 vehicles would bring only a small reduction and emit, e.g., the same as EURO 4 vehicles in real-driving, emissions from light duty diesel vehicles would only slightly decline after 2015 to about 1200 kt. In that case emissions from all road vehicles would be 20% higher than in the baseline scenario in the year 2020, more than twice as high in the year 2030 and almost three times higher in 2035, however still down by 70% compared to the year 2005.

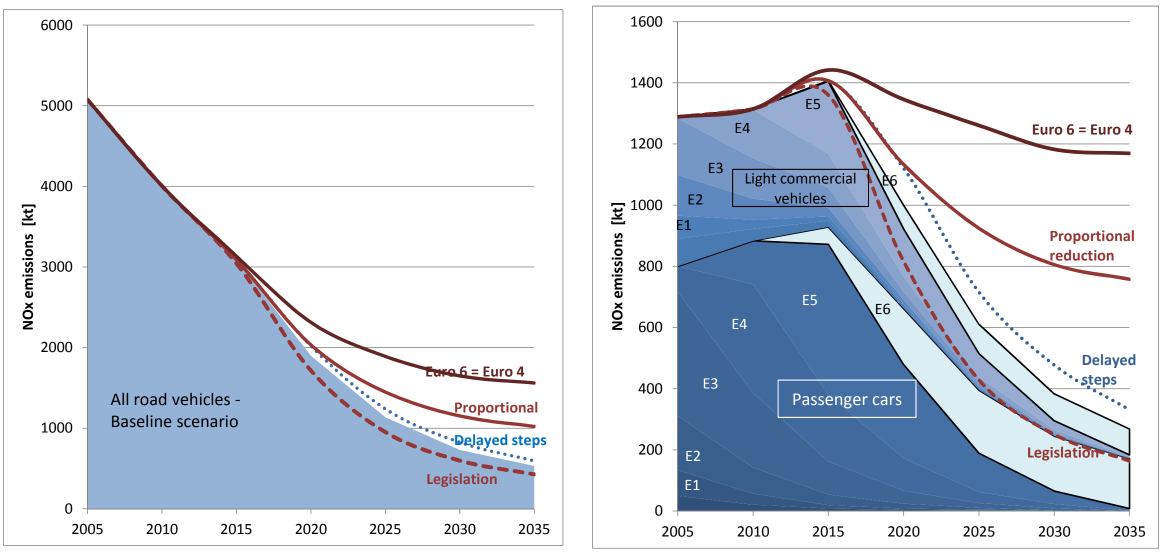

Figure 5.4: Development of NO_x emissions from all road vehicles in the EU-27 (left panel) in the baseline scenario (shaded area) and under the different assumptions for real-driving emissions from light duty diesel vehicles. Right panel: Close-up on NO_x emissions from light duty diesel vehicles under the different scenarios.

Clearly the future level of NO_x emissions, and consequently the resulting NO_2 ambient concentrations depend on the effectiveness of EURO 6 emission controls under real-driving conditions. Emissions from light duty diesel vehicles will only decrease by about the same rate as, e.g., those from trucks if the EURO 6 norm proves effective. At the moment this does not seem fully guaranteed as indicated by preliminary measurements (Demuynck et al. 2012; Hausberger 2012), the still pending modification of the test cycle, and the open definition of real-driving controls.

The impact different NO_x emissions on the compliance with NO_2 air quality limit values will be analysed in a companion report.

5.5 Impacts of real-driving EURO 2-5 emission factors

NO_x emission from light duty diesel vehicles under real-world driving conditions have been substantially higher than the emissions over the legislative driving cycle (NEDC) from EURO 2 vehicles onwards, unlike, e.g., those of gasoline cars (Carslaw et al. 2011; Hausberger 2010; Weiss et al. 2011). Together with their increase in mileage, this has led to higher NO_x emissions than anticipated in the 2005 Thematic Strategy on Air Pollution.

This sensitivity analysis explores the increase in NO_x emissions from light duty diesel vehicles that can be attributed to the different developments of test cycle and real-driving emissions in the past (Table 5-4).

Euro standard	Limit value (type approval) g NOx/km	Successive reduction rates	Scen. Euro 2ff (real-driving) g NOx/km	Scen. Euro 3ff (real-driving) g NOx/km	Scen. Euro 4ff (real-driving) g NOx/km
EURO 1	0.99	-72%	0.73*	0.73*	0.73*
EURO 2	0.58	-42%	0.43	0.89*	0.89*
EURO 3	0.50	-14%	0.37	0.77	0.87*
EURO 4	0.25	-50%	0.18	0.38	0.44
EURO 5	0.18	-28%	0.13	0.28	0.31
EURO 6	0.08	-56%	0.06	0.12	0.14

Table 5-4: Limit values over the type approval cycle for diesel passenger cars and emission factors derived for real-driving conditions, by applying the successive reduction rates to the value measured over the Common Artemis Driving Cycle (marked with *).

If average real-driving emission factors would have met the type approval limit values, NO_x emissions in Europe would be substantially lower, particularly between 2005 and 2025 (Figure 5.5). Differences to the baseline scenario will only diminish by 2035 when essentially the entire fleet will consist of EURO 6 vehicles.

If unit emissions from EURO 2 and all younger vehicles would have decreased at the same rate as the type approval values, emissions from light duty diesel vehicles could have been more than 500 kt or 40% lower in 2005, almost 800 kt or 60% lower in 2010 and 1000 kt or 75% lower in 2015 compared to the baseline (Figure 5.5).

If unit emissions from EURO 3 and all younger vehicles would have decreased at the same rate as the respective type approval values, emissions from light duty diesel vehicles could have been 20%, 40% and 60% below the baseline in 2005, 2010 and 2015 respectively. Even in 2030 they would have been only half of the projected baseline emissions.

With emission reductions effective from EURO 4 onwards, emissions of NO_x from light duty diesel vehicles would have declined from 2005 onwards. They would have been 20% and almost 50% below the baseline in 2010 and 2015, respectively.

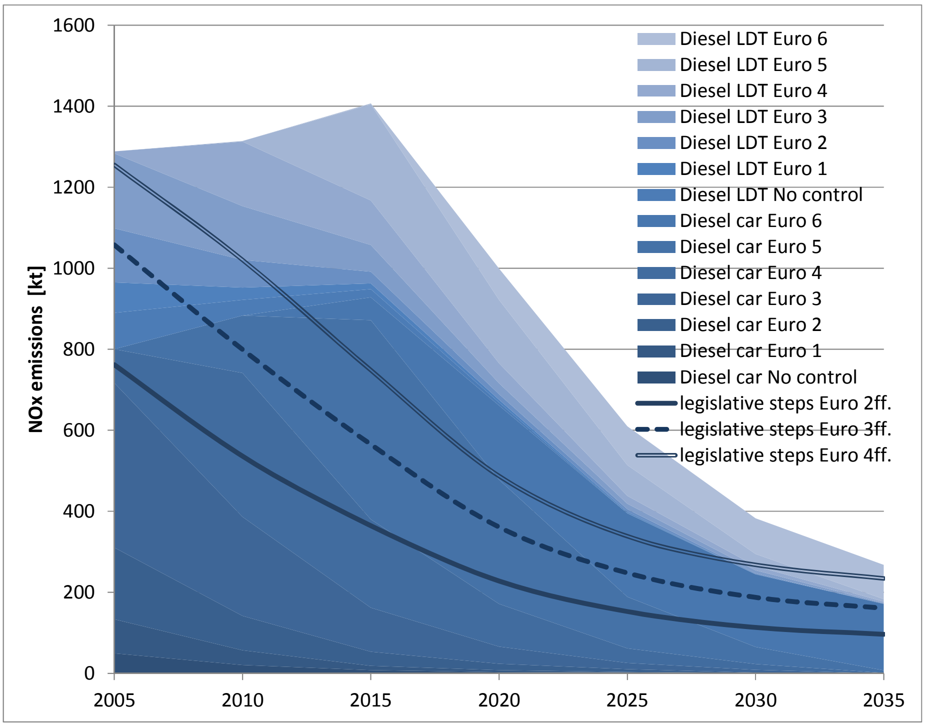

Figure 5.5: Development of NO_x emissions from light duty diesel vehicles in the baseline scenario (shaded area) and assuming already EURO 2, or EURO 3 or EURO 4 technologies would have delivered the intended reductions.

Table 5-5: Sensitivity analyses of NO_x emissions from light duty diesel vehicles assuming reduction steps for real-world emissions from EURO 2, EURO 3 or EURO 4 onwards, compared to emissions in the baseline scenario.

	Emissions from LDDV			*Emissions from all road vehicles*		
	2005	2020	2030	2005	2020	2030
Baseline (kt)	1289	999	383	5074	1898	730
	Change vs. Baseline			Change vs. Baseline		
Compliance from EURO 2ff.	-41%	-77%	-70%	-10%	-41%	-37%
Compliance from EURO 3ff.	-18%	-64%	-51%	-5%	-34%	-27%
Compliance from EURO 4ff.	-3%	-51%	-30%	-1%	-27%	-16%

Lower real-driving emissions from light duty diesel vehicles would have helped several countries to attain their NEC ceilings in 2010 (Table 5-6). With unit emissions close to the limit values (scenarios Euro 2ff or Limit values) resulting total NO_x emissions from all sectors could have stayed below the NEC 2010 ceiling in Malta, the Netherlands, Slovenia, Sweden and the United Kingdom, even including the growth in activity for diesel vehicles. Attainment would have been easier in Denmark and Finland, while for France and Germany the ceiling would have still been exceeded by a few percent. For all other countries the threshold would have been either exceeded much less or attained with a much greater margin. Total NO_x emissions in EU27 could have been up to 10% lower in the year 2010.

Table 5-6: Total national NOx emissions in the year 2010 under different assumptions for the real-driving emissions from light duty diesel vehicles in each country, compared to the NEC ceiling and the projected emission (not the officially reported).

Country	NEC ceiling 2010 kt NOx	Baseline 2010 kt NOx	Scen. Euro 4ff – 2010 kt NOx	Scen. Euro 3ff – 2010 kt NOx	Scen. Euro 2ff – 2010 kt NOx	Scen. limit values -2010 kt NOx	Share of LDDV in 2010 % in total em.
Austria	103	166	160	158	141	150	20%
Belgium	176	241	226	220	196	207	25%
Bulgaria	247	105	105	105	101	104	8%
Cyprus	23	19	19	19	18	18	17%
Czech Rep.	286	220	218	218	208	213	10%
Denmark	127	126	123	123	116	119	11%
Estonia	60	29	28	28	28	28	5%
Finland	170	162	na.	na.	na.	156	9%
France	810	1015	971	962	835	880	27%
Germany	1051	1195	1160	1151	1074	1106	14%
Greece	344	281	281	281	275	277	4%
Hungary	198	141	139	139	133	136	9%
Ireland	65	94	na.	na.	na.	83	20%
Italy	990	1083	1056	1051	978	1014	14%
Latvia	61	35	34	34	32	33	14%
Lithuania	110	48	48	48	47	47	6%
Luxembourg	11	40	37	36	30	32	33%
Malta	8	8	8	8	7	8	12%
Netherlands	260	276	263	263	232	238	23%
Poland	879	713	710	707	678	691	9%
Portugal	250	191	187	187	171	178	18%
Romania	437	250	249	249	245	246	3%
Slovakia	130	81	81	81	79	79	6%
Slovenia	45	47	46	46	43	45	11%
Spain	847	1080	1052	1049	964	997	16%
Sweden	148	157	154	154	147	149	9%
UK	1167	1193	1165	1164	1094	1121	11%
EU-27	9003	8998	8776	8737	8118	8357	15%

It should be noted that the analysis adopts for all countries the ‘fuel sold’ concept, while some countries report their emissions based on ‘fuel used’ statistics.

6 Conclusions

In 2005, emissions from mobile (road and non-road) sources contributed about 60% to total NO_x emissions in the EU, 20% to total $PM_{2.5}$, and 30% to total VOC emissions. Road sources emitted more than 70% of NO_x and VOC of all mobile sources, and more than 60% of $PM_{2.5}$.

From 2005 to 2010, implementation of EU legislation has reduced NO_x from mobile sources by 18%, PM by 21% and VOC by 34%. For NO_x, the decline is lower than emission reductions from stationary sources (-26%), so that the relative importance of the transport sector has increased despite the EURO legislation. Especially for NO_x, the recent drop in emissions is less than what was anticipated by the 2005 Thematic Strategy on Air Pollution. The major reason for this shortfall are problems in the implementation of NO_x limit values for light duty diesel vehicles, where changes in real-driving emissions did not follow the improvements in the type approval limit values. As a consequence, by 2015 NO_x emissions from light duty diesel vehicles will be a factor two higher compared to a situation where real-driving emissions of the EURO 2 to EURO 5 standards would have followed the trends in the type approval limit values.

It is estimated that successful implementation of the EURO 6 standards for diesel vehicles (assuming 50% higher real-driving emissions than the type approval value to allow for degradation over time and uncertainties in the driving cycles) would lead to a decrease of NO_x emissions from 2015 onwards. Up to 2020, NO_x emissions from road transport would decline then by more than 60% compared to 2005, by 78% in 2025, and by 86% in 2030.

PM emissions from road transport would fall by 62% in 2020 and by 70% in 2030, and VOC by up to 80% until 2030. For PM, the majority of emissions will be caused by non-exhaust sources (tyre and brake wear, road abrasion).

For non-road mobile machinery, implementation of the agreed emission controls along the current schedule should cut NO_x emissions in 2020 by 40% and in 2030 by 60% compared to 2005. Emissions from $PM_{2.5}$ are projected to decrease by 55% in 2020 and by almost 75% in 2030; the reduction for VOC emissions is estimated at 50% by 2020 and 60% until 2030. Least changes are expected from ships due to their long lifetime and the slow penetration of new technology.

If these changes materialize, emissions from mobile sources would decline faster than those of stationary sources. Especially road transport would lower its share in total emissions, e.g., for NO_x from 44% in 2005 to 17% in 2030, for PM from 14% to 7% and for VOC from 23% to 9%.

There is a potential for further emission reductions also for non-road mobile machinery, where the introduction of Stage V controls in 2020 could cut NO_x emissions from NRMM by 15% in 2030 and PM2.5 emissions by 26%. For further reductions ships and aircraft would need to contribute more.

For road vehicles, the introduction of hypothetical further EURO standard after 2020, with real-world emission factors around 20% below the EURO 6/VI limit values could reduce NO_x emissions from road vehicles by 20% below the baseline projection for 2030.

How much NO_x emission from road vehicles will eventually decline depends strongly on real-driving emissions of EURO 6 light duty diesel vehicles. For instance, if the second and important reduction step (EURO 6.2) were delayed from 2017 to 2020, NO_x emissions from road vehicles would be 6% and 13% higher in 2020 and 2030, respectively. If real-driving emissions would actually be as low as the limit value from 2015 onwards, NO_x emissions from road vehicles would be 10% and 18% lower than the baseline projection for years 2020 and 2030, respectively. However, if real driving EURO 6 emissions were reduced from the EURO 5 level only by the same rate as the nominal limit value decreases, emissions from all road vehicles would be 7% and 60% higher than in the baseline in 2020and 2030. In case emissions from EURO 6 vehicles were some 30% lower than EURO 5 vehicles in real-driving, NO_x emissions from all road vehicles would be 20% and 120% higher than the baseline projection in 2020 and 2030, respectively, although 55% and 68% lower than in 2005.

For PM, non-exhaust emissions (road abrasion, brake and tyre wear) will become the major source in the future, and total mass of PM emissions will critically depend on the development of these sources.

Implications of these further measures on air quality at urban hot spots will be reported in Part 2 of this report at a later stage.

References

Amann, Markus, Imrich Bertok, Jens Borken-Kleefeld, Janusz Cofala, Chris Heyes, Lena Höglund-Isaksson, Zbigniew Klimont, et al. 2011. “Cost-effective Control of Air Quality and Greenhouse Gases in Europe: Modeling and Policy Applications.” *Environmental Modelling & Software* 26 (12): 1489–1501. doi:10.1016/j.envsoft.2011.07.012.

Amann, Markus, Jens Borken-Kleefeld, Janusz Cofala, Chris Heyes, Zbigniew Klimont, Peter Rafaj, Pallav Purohit, Wolfgang Schoepp, and Wilfried Winiwarter. 2012. *Future Emissions of Air Pollutants in Europe – Current Legislation Baseline and the Scope for Further Reductions. TSAP Report #1*. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Carslaw, D., Sean Beevers, E. Westmoreland, Martin Williams, J. Tate, T. Murrells, John R. Stedman, et al. 2011. *Trends in NOX and NO2 Emissions and Ambient Measurements in the UK*.

CEC. 2005. *Communication from the Commission to the Council and the European Parliament on a Thematic Strategy on Air Pollution*. Brussels, Belgium: Commission of the European Communities.

Demuynck, Joachim, Dirk Bosteels, Michel De Paepe, Cécile Favre, John May, and Sebastian Verhelst. 2012. “Recommendations for the New WLTP Cycle Based on an Analysis of Vehicle Emission Measurements on NEDC and CADC.” *Energy Policy*

EC. 2011a. *A Roadmap for Moving to a Competitive Low Carbon Economy in 2050*. Brussels, Belgium: European Commission. http://ec.europa.eu/clima/policies/roadmap/index_en.htm.

———. 2011b. *Impact Assessment - Accompanying Document to the White Paper “Roadmap to a Single European Transport Area – Towards a Competitive and Resource Efficient Transport System”*. Brussels: European Commission.

Hausberger, S. 2010. *Fuel Consumption and Emissions of Modern Passenger Cars*. TU Graz, Institute for Internal Combustion and Thermodynamics.

———. 2012. “Overview of the Measurement Programs on LDV and HDV” presented at the Annual Plenary Meeting of ERMES, September 27, Brussels, Belgium.

Mehlhart, Georg, Cornelia Merz, Lars Akkermans, and Jorgen Jordal-Jorgensen. 2011. *European Second-hand Car Market Analysis*. Final Report. Darmstadt: European Commission DG Climate Action.

Mellios, Giorgios, Thomas Papageorgiou, and Leonidas Ntziachristos. *Centralised and National Submissions of Transport Emissions*. ETC/ACC Technical Paper 2009/11. Copenhagen, Denmark: European Topic Centre on Air and Climate Change.

Ntziachristos, L., and C. Kouridis. 2008. *The Tremove/Copert Transport Models*. A LIFE+ EC4MACS report. European Commission (EC).

Ntziachristos, L., G. Mellios, C. Kouridis, T. Papageorgiou, M. Theodosopoulou, Z. Samaras, K.-H. Zierock, et al. 2008. *European Database of Vehicle Stock for the Calculation and Forecast of Pollutant and Greenhouse Gases Emissions with TREMOVE and COPERT*. Thessaloniki, Greece.

Smit, Robin, Leonidas Ntziachristos, and Paul Boulter. 2010. “Validation of Road Vehicle and Traffic Emission Models – A Review and Meta-analysis.” *Atmospheric Environment* 44 (25)

Weiss, Martin, Pierre Bonnel, Rudolf Hummel, Alessio Provenza, and Urbano Manfredi. 2011. “On-Road Emissions of Light-Duty Vehicles in Europe.” *Environmental Science & Technology* 45 (19)

Annex:– Transport emissions by country

The following tables document the emissions of air pollutants from road and non-road vehicles, aggregated by SNAP sectors, per Member State in the baseline scenario and MTFR scenarios. These figures serve as a starting point for the bilateral consultations between IIASA and experts from Member States to arrive at agreed numbers for the final TSAP baseline.

Table 6-1: NO_x emissions from road transport (SNAP sector 7) in all EU27 Member States in 2005 and in 2020, 2030 and 2050 according to the Baseline and the MTFR scenario, as well as EU27 totals.

		Draft Baseline Scenario			*Draft MTFR Scenario*		
NO_x	kt	kt	kt	kt	kt	kt	kt
SNAP 7: Road transport	2005	2020	2030	2050	2020	2030	2050
Austria	120	39	13	10	36	10	8
Belgium	142	58	20	14	50	15	10
Bulgaria	62	26	19	6	26	18	4
Cyprus	10	5	3	1	5	3	1
Czech Republic	110	61	28	11	59	26	9
Denmark	65	20	8	6	19	7	4
Estonia	17	6	3	1	6	2	1
Finland	66	21	9	5	20	8	3
France	737	233	83	68	208	57	49
Germany	773	216	75	59	194	57	46
Greece	95	37	17	9	36	16	7
Hungary	80	31	12	8	31	10	6
Ireland	55	35	11	9	33	8	6
Italy	706	235	94	62	217	76	47
Latvia	17	13	5	2	13	4	1
Lithuania	33	14	6	3	13	5	2
Luxembourg	43	17	6	4	15	5	3
Malta	4	2	1	0	2	1	0
Netherlands	160	59	22	17	51	15	12
Poland	220	155	69	29	149	61	22
Portugal	113	60	15	11	58	12	8
Romania	102	52	22	10	51	20	8
Slovakia	38	19	10	3	18	9	3
Slovenia	27	11	5	3	10	4	3
Spain	645	295	109	59	278	92	44
Sweden	109	26	10	9	24	8	7
UK	525	146	61	57	129	44	43
EU 27: Sum Road transport	5074	1893	733	473	1751	591	360
EU 27: Sum all sectors	11501	5768	4027	3573	4635	2873	2329

Table 6-2: NO_x emissions from non-road transport (SNAP sector 8) in all EU27 Member States in 2005 and in 2020, 2030 and 2050 according to the Baseline and the MTFR scenario, as well as EU27 totals.

		Draft Baseline Scenario			*Draft MTFR Scenario*		
NO_x	kt	kt	kt	kt	kt	kt	kt
SNAP 8: Non-road transport	2005	2020	2030	2050	2020	2030	2050
Austria	22	10.1	5.6	4.6	10.0	5.1	3.7
Belgium	30	18.9	13.4	11.3	18.7	12.5	8.7
Bulgaria	12	6.0	3.2	2.2	6.0	2.9	1.8
Cyprus	2	0.7	0.4	0.4	0.7	0.3	0.3
Czech Republic	23	10.4	3.8	1.7	10.3	3.3	0.9
Denmark	54	27.9	19.2	17.4	27.8	18.6	16.1
Estonia	7	2.4	0.9	0.7	2.3	0.9	0.6
Finland	48	24.8	14.8	13.8	24.7	14.4	13.2
France	225	118.6	76.1	60.7	117.6	70.2	46.5
Germany	141	79.3	45.3	37.5	78.5	41.7	28.1
Greece	78	61.1	49.4	46.0	61.0	48.5	45.0
Hungary	13	6.1	2.2	1.5	6.1	2.0	1.2
Ireland	18	10.7	8.1	7.1	10.6	7.7	6.2
Italy	268	186.3	154.4	146.4	185.9	151.8	141.9
Latvia	5	3.1	0.4	0.4	3.1	0.4	0.4
Lithuania	5	4.2	2.6	1.9	4.1	2.1	0.5
Luxembourg	1	0.8	0.5	0.4	0.8	0.4	0.2
Malta	0	0.1	0.1	0.1	0.1	0.1	0.1
Netherlands	75	40.2	32.3	28.7	39.2	27.6	15.5
Poland	76	49.1	19.9	11.4	48.8	17.6	7.9
Portugal	23	12.5	8.8	8.2	12.5	8.5	7.5
Romania	26	23.3	16.9	12.0	22.9	14.7	5.5
Slovakia	2	1.3	0.9	0.6	1.3	0.8	0.2
Slovenia	6	3.7	1.4	1.1	3.7	1.3	0.9
Spain	238	115.4	66.0	55.0	114.8	62.4	49.7
Sweden	51	21.6	17.2	17.4	21.6	16.8	16.7
UK	267	178.3	119.5	116.0	177.6	116.1	111.4
EU 27: Sum Non-road transport	1717	1017	683	604	1010	648	530
EU 27: Sum all sectors	11501	5768	4027	3573	4635	2873	2329

Table 6-3: PM_{10} emissions from road transport (SNAP sector 7) in all EU27 Member States in 2005 and in 2020, 2030 and 2050 according to the Baseline and the MTFR scenario, as well as EU27 totals.

PM_{10}		***Draft Baseline Scenario***			***Draft MTFR Scenario***		
	kt	kt	kt	kt	kt	kt	kt
SNAP 7: Road transport	2005	2020	2030	2050	2020	2030	2050
Austria	7.4	4.0	3.9	3.8	4.0	3.9	3.7
Belgium	9.1	4.3	4.2	4.2	4.3	4.2	4.2
Bulgaria	3.8	2.0	2.1	1.3	2.0	2.1	1.3
Cyprus	0.8	0.4	0.3	0.3	0.4	0.3	0.3
Czech Republic	9.2	5.3	4.1	3.8	5.3	4.1	3.8
Denmark	3.8	2.0	1.9	1.9	2.0	1.9	1.9
Estonia	0.8	0.5	0.4	0.4	0.5	0.4	0.4
Finland	8.0	6.6	6.8	6.4	6.6	6.8	6.3
France	46.8	18.9	20.1	20.1	18.8	19.8	19.8
Germany	45.4	26.1	25.4	23.5	26.1	25.2	23.3
Greece	5.2	3.1	2.8	2.6	3.1	2.8	2.6
Hungary	5.1	3.2	2.8	2.8	3.2	2.8	2.8
Ireland	4.3	2.6	2.3	2.6	2.6	2.3	2.5
Italy	44.8	21.7	20.1	19.0	21.7	19.9	18.8
Latvia	1.4	0.7	0.6	0.5	0.7	0.6	0.5
Lithuania	1.6	0.9	0.8	0.8	0.9	0.8	0.8
Luxembourg	2.5	1.4	1.3	1.3	1.4	1.3	1.3
Malta	0.3	0.2	0.1	0.1	0.2	0.1	0.1
Netherlands	10.8	4.4	4.5	4.4	4.3	4.4	4.3
Poland	11.0	10.3	8.7	7.8	10.3	8.7	7.7
Portugal	7.2	4.5	2.9	2.9	4.5	2.9	2.9
Romania	4.7	3.2	3.0	3.0	3.2	3.0	3.0
Slovakia	2.4	1.7	1.5	1.3	1.7	1.5	1.3
Slovenia	1.5	1.4	1.6	1.7	1.4	1.5	1.7
Spain	34.8	22.7	21.0	19.7	22.7	20.9	19.6
Sweden	11.0	9.6	10.9	10.4	9.6	10.8	10.4
UK	31.8	16.5	17.9	18.2	16.5	17.6	17.9
EU 27: Sum Road transport	315	178	172	165	178	171	163
EU 27: Sum all sectors	2617	1932	1791	1717	1221	1053	1001

Table 6-4: PM_{10} emissions from non-road transport (SNAP sector 8) in all EU27 Member States in 2005 and in 2020, 2030 and 2050 according to the Baseline and the MTFR scenario, as well as EU27 totals.

PM_{10} SNAP 8: Non-road transport	kt 2005	*Draft Baseline Scenario* kt 2020	kt 2030	kt 2050	*Draft MTFR Scenario* kt 2020	kt 2030	kt 2050
Austria	2.2	0.75	0.31	0.22	0.75	0.26	0.13
Belgium	2.7	1.33	0.88	0.68	1.32	0.83	0.57
Bulgaria	1.0	0.39	0.16	0.11	0.39	0.14	0.07
Cyprus	0.2	0.05	0.02	0.03	0.05	0.02	0.02
Czech Republic	1.9	0.75	0.26	0.16	0.75	0.22	0.10
Denmark	3.7	1.38	0.80	0.69	1.37	0.74	0.59
Estonia	0.5	0.15	0.04	0.02	0.15	0.04	0.02
Finland	4.1	1.36	0.76	0.72	1.36	0.71	0.65
France	22.3	10.32	6.64	5.40	10.24	6.15	4.52
Germany	16.4	5.28	2.05	1.53	5.24	1.74	0.99
Greece	6.4	3.89	3.05	2.86	3.88	2.95	2.71
Hungary	1.2	0.44	0.11	0.07	0.44	0.09	0.04
Ireland	1.5	0.61	0.34	0.22	0.61	0.30	0.16
Italy	23.7	12.12	9.80	9.35	12.09	9.52	8.89
Latvia	0.4	0.23	0.03	0.03	0.23	0.02	0.02
Lithuania	0.5	0.31	0.14	0.04	0.31	0.14	0.02
Luxembourg	0.1	0.06	0.03	0.02	0.06	0.02	0.01
Malta	0.0	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	4.0	1.39	0.94	0.65	1.36	0.82	0.41
Poland	7.5	3.83	1.47	1.06	3.81	1.22	0.67
Portugal	1.9	0.87	0.59	0.52	0.86	0.56	0.47
Romania	2.3	1.83	1.18	0.58	1.80	1.08	0.34
Slovakia	0.2	0.12	0.07	0.03	0.11	0.06	0.02
Slovenia	0.5	0.23	0.07	0.06	0.22	0.06	0.04
Spain	19.1	7.20	3.17	2.61	7.17	2.80	2.01
Sweden	4.4	1.27	0.98	0.99	1.26	0.94	0.93
UK	17.8	7.76	4.00	3.99	7.72	3.59	3.42
EU 27: Sum Non-road transport	147	64	38	33	64	35	28
EU 27: Sum all sectors	2617	1932	1792	1717	1221	1053	1001

Table 6-5: $PM_{2.5}$ emissions from road transport (SNAP sector 7) in all EU27 Member States in 2005 and in 2020, 2030 and 2050 according to the Baseline and the MTFR scenario, as well as EU27 totals.

$PM_{2.5}$ SNAP 7: Road transport	kt 2005	*Draft Baseline Scenario* kt 2020	kt 2030	kt 2050	*Draft MTFR Scenario* kt 2020	kt 2030	kt 2050
Austria	5.8	2.0	1.7	1.6	2.0	1.7	1.6
Belgium	7.6	2.3	1.9	1.9	2.3	1.8	1.8
Bulgaria	3.4	1.4	1.4	0.6	1.4	1.3	0.6
Cyprus	0.7	0.3	0.2	0.1	0.3	0.2	0.1
Czech Republic	8.0	3.4	2.0	1.7	3.4	2.0	1.7
Denmark	3.0	1.1	0.9	0.8	1.1	0.9	0.8
Estonia	0.6	0.3	0.2	0.2	0.3	0.2	0.2
Finland	3.8	1.4	1.1	1.1	1.4	1.1	1.0
France	39.0	9.7	8.7	8.7	9.7	8.4	8.3
Germany	34.2	12.5	11.1	10.2	12.5	10.8	9.9
Greece	4.1	1.8	1.4	1.2	1.8	1.4	1.2
Hungary	4.3	1.8	1.3	1.2	1.8	1.3	1.2
Ireland	3.4	1.4	0.8	0.9	1.4	0.8	0.9
Italy	36.7	12.4	9.3	8.4	12.4	9.1	8.2
Latvia	1.2	0.5	0.3	0.2	0.5	0.3	0.2
Lithuania	1.3	0.5	0.4	0.3	0.5	0.4	0.3
Luxembourg	2.0	0.8	0.6	0.6	0.8	0.6	0.5
Malta	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Netherlands	8.9	2.2	2.0	2.0	2.2	1.9	1.9
Poland	8.8	6.2	4.3	3.5	6.2	4.3	3.4
Portugal	5.9	3.0	1.3	1.3	3.0	1.3	1.3
Romania	4.0	1.8	1.4	1.3	1.8	1.4	1.3
Slovakia	2.0	0.9	0.7	0.5	0.9	0.7	0.5
Slovenia	1.1	0.7	0.7	0.7	0.7	0.7	0.7
Spain	28.0	12.9	9.7	8.6	12.9	9.6	8.4
Sweden	7.3	5.1	5.7	5.4	5.1	5.6	5.4
UK	24.3	7.8	7.9	8.0	7.7	7.6	7.7
EU 27: Sum Road transport	250	94	77	71	94	75	69
EU 27: Sum all sectors	1833	1299	1145	1065	759	580	522

Table 6-6: $PM_{2.5}$ emissions from non-road transport (SNAP sector 8) in all EU27 Member States in 2005 and in 2020, 2030 and 2050 according to the Baseline and the MTFR scenario, as well as EU27 totals.

$PM_{2.5}$ **SNAP 8: Non-road transport**	kt 2005	*Draft Baseline Scenario* kt 2020	kt 2030	kt 2050	*Draft MTFR Scenario* kt 2020	kt 2030	kt 2050
Austria	2.04	0.71	0.29	0.19	0.71	0.24	0.13
Belgium	2.53	1.25	0.82	0.60	1.25	0.78	0.54
Bulgaria	0.95	0.37	0.16	0.10	0.37	0.13	0.07
Cyprus	0.16	0.04	0.02	0.02	0.04	0.01	0.01
Czech Republic	1.83	0.71	0.25	0.15	0.71	0.21	0.09
Denmark	3.53	1.30	0.75	0.65	1.30	0.70	0.56
Estonia	0.52	0.14	0.04	0.02	0.14	0.03	0.02
Finland	3.84	1.29	0.72	0.68	1.28	0.67	0.61
France	21.06	9.72	6.19	4.92	9.68	5.82	4.27
Germany	15.53	4.98	1.90	1.37	4.95	1.64	0.92
Greece	6.03	3.68	2.89	2.71	3.68	2.80	2.57
Hungary	1.17	0.42	0.10	0.06	0.41	0.08	0.03
Ireland	1.43	0.58	0.31	0.20	0.57	0.29	0.15
Italy	22.31	11.43	9.24	8.80	11.41	8.98	8.39
Latvia	0.39	0.22	0.02	0.02	0.22	0.02	0.02
Lithuania	0.44	0.29	0.14	0.05	0.29	0.13	0.02
Luxembourg	0.10	0.05	0.03	0.02	0.05	0.02	0.01
Malta	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	3.78	1.29	0.84	0.49	1.29	0.78	0.39
Poland	7.04	3.63	1.39	1.00	3.60	1.16	0.64
Portugal	1.77	0.82	0.55	0.49	0.82	0.52	0.44
Romania	2.22	1.71	1.06	0.42	1.71	1.02	0.32
Slovakia	0.22	0.11	0.06	0.03	0.11	0.06	0.02
Slovenia	0.49	0.21	0.07	0.06	0.21	0.05	0.04
Spain	18.07	6.82	3.01	2.47	6.79	2.65	1.90
Sweden	4.17	1.20	0.93	0.93	1.19	0.89	0.88
UK	16.83	7.34	3.78	3.77	7.30	3.38	3.23
EU 27: Sum Non-road transport	138	60	36	30	60	33	26
EU 27: Sum all sectors	1833	1299	1145	1065	759	580	522

Table 6-7: BC emissions from road transport (SNAP sector 7) in all EU27 Member States in 2005 and in 2020, 2030 and 2050 according to the Baseline and the MTFR scenario, as well as EU27 totals.

BC SNAP 7: Road transport	kt 2005	*Draft Baseline Scenario* kt 2020	kt 2030	kt 2050	*Draft MTFR Scenario* kt 2020	kt 2030	kt 2050
Austria	3.6	0.68	0.32	0.28	0.68	0.32	0.28
Belgium	4.9	0.86	0.37	0.32	0.86	0.38	0.33
Bulgaria	1.8	0.72	0.58	0.11	0.72	0.58	0.11
Cyprus	0.4	0.12	0.05	0.02	0.12	0.05	0.02
Czech Republic	3.9	1.40	0.50	0.29	1.40	0.50	0.30
Denmark	1.7	0.43	0.18	0.14	0.43	0.18	0.14
Estonia	0.3	0.10	0.05	0.03	0.10	0.05	0.03
Finland	2.1	0.56	0.29	0.22	0.56	0.29	0.22
France	24.2	3.40	1.60	1.57	3.41	1.65	1.64
Germany	19.0	3.35	1.91	1.72	3.35	1.93	1.74
Greece	1.8	0.62	0.32	0.20	0.62	0.32	0.21
Hungary	2.2	0.73	0.28	0.20	0.73	0.28	0.21
Ireland	2.1	0.64	0.18	0.19	0.64	0.20	0.21
Italy	19.5	4.86	2.03	1.44	4.87	2.06	1.48
Latvia	0.7	0.23	0.08	0.04	0.23	0.09	0.04
Lithuania	0.7	0.20	0.09	0.06	0.20	0.09	0.06
Luxembourg	1.3	0.28	0.12	0.10	0.28	0.12	0.10
Malta	0.1	0.03	0.01	0.01	0.03	0.01	0.01
Netherlands	5.8	0.67	0.36	0.34	0.67	0.37	0.35
Poland	4.8	2.66	1.16	0.60	2.66	1.19	0.63
Portugal	3.3	1.46	0.25	0.22	1.46	0.26	0.23
Romania	2.0	0.74	0.34	0.22	0.74	0.34	0.23
Slovakia	1.0	0.36	0.20	0.09	0.36	0.20	0.10
Slovenia	0.6	0.18	0.12	0.12	0.18	0.12	0.12
Spain	16.6	5.58	2.31	1.47	5.58	2.35	1.51
Sweden	2.5	0.49	0.40	0.38	0.49	0.41	0.39
UK	14.6	1.80	1.31	1.33	1.80	1.31	1.33
EU 27: Sum Road transport	141	33	15	12	33	16	12
EU 27: Sum all sectors	375	210	157	139	143	68	55

Table 6-8: BC emissions from non-road transport (SNAP sector 8) in all EU27 Member States in 2005 and in 2020, 2030 and 2050 according to the Baseline and the MTFR scenario, as well as EU27 totals.

BC		*Draft Baseline Scenario*			*Draft MTFR Scenario*		
	kt	kt	kt	kt	kt	kt	kt
SNAP 8: Non-road transport	2005	2020	2030	2050	2020	2030	2050
Austria	0.88	0.27	0.08	0.04	0.27	0.08	0.03
Belgium	0.99	0.47	0.29	0.19	0.47	0.29	0.19
Bulgaria	0.40	0.14	0.05	0.02	0.14	0.05	0.02
Cyprus	0.08	0.02	0.00	0.00	0.02	0.00	0.00
Czech Republic	0.75	0.27	0.07	0.03	0.27	0.07	0.02
Denmark	1.39	0.48	0.25	0.20	0.48	0.25	0.20
Estonia	0.22	0.06	0.01	0.01	0.06	0.01	0.01
Finland	1.45	0.44	0.23	0.21	0.44	0.23	0.21
France	8.69	3.70	2.16	1.58	3.70	2.15	1.55
Germany	6.31	1.81	0.51	0.25	1.81	0.50	0.23
Greece	2.31	1.40	1.06	0.97	1.40	1.06	0.97
Hungary	0.48	0.16	0.03	0.01	0.16	0.03	0.01
Ireland	0.60	0.22	0.11	0.06	0.22	0.11	0.05
Italy	7.51	3.87	2.93	2.72	3.87	2.92	2.71
Latvia	0.17	0.09	0.01	0.01	0.09	0.01	0.01
Lithuania	0.19	0.13	0.05	0.01	0.13	0.05	0.00
Luxembourg	0.05	0.02	0.01	0.00	0.02	0.01	0.00
Malta	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	1.59	0.50	0.29	0.14	0.50	0.28	0.13
Poland	2.70	1.33	0.38	0.19	1.33	0.37	0.19
Portugal	0.73	0.31	0.19	0.16	0.31	0.19	0.16
Romania	0.91	0.68	0.40	0.12	0.68	0.40	0.11
Slovakia	0.09	0.04	0.02	0.01	0.04	0.02	0.00
Slovenia	0.20	0.08	0.01	0.01	0.08	0.01	0.01
Spain	7.60	2.65	0.94	0.67	2.65	0.93	0.67
Sweden	1.42	0.40	0.29	0.29	0.40	0.29	0.29
UK	7.31	2.84	1.16	1.14	2.84	1.16	1.14
EU 27: Sum Non-road transport	55	22	12	9	22	11	9
EU 27: Sum all sectors	375	210	157	139	143	68	55

Table 6-9: OC emissions from road transport (SNAP sector 7) in all EU27 Member States in 2005 and in 2020, 2030 and 2050 according to the Baseline and the MTFR scenario, as well as EU27 totals.

		Draft Baseline Scenario			***Draft MTFR Scenario***		
OC	kt	kt	kt	kt	kt	kt	kt
SNAP 7: Road transport	2005	2020	2030	2050	2020	2030	2050
Austria	1.5	0.88	0.90	0.88	0.88	0.91	0.89
Belgium	1.7	0.91	0.96	0.98	0.91	0.97	0.99
Bulgaria	1.1	0.42	0.50	0.31	0.42	0.50	0.32
Cyprus	0.2	0.09	0.08	0.07	0.09	0.08	0.07
Czech Republic	2.7	1.31	1.00	0.92	1.31	1.01	0.93
Denmark	0.8	0.43	0.44	0.43	0.43	0.44	0.44
Estonia	0.2	0.10	0.10	0.10	0.10	0.10	0.10
Finland	1.4	0.88	0.89	0.86	0.87	0.89	0.85
France	9.9	4.22	4.76	4.78	4.23	4.85	4.88
Germany	9.8	5.84	5.86	5.42	5.85	5.89	5.46
Greece	1.5	0.75	0.68	0.62	0.75	0.68	0.63
Hungary	1.4	0.74	0.65	0.64	0.74	0.66	0.66
Ireland	0.9	0.58	0.52	0.59	0.58	0.53	0.59
Italy	11.3	4.88	4.62	4.42	4.89	4.68	4.50
Latvia	0.4	0.15	0.13	0.12	0.15	0.13	0.12
Lithuania	0.4	0.21	0.19	0.18	0.21	0.19	0.18
Luxembourg	0.5	0.30	0.30	0.30	0.30	0.31	0.30
Malta	0.1	0.03	0.03	0.03	0.03	0.03	0.03
Netherlands	2.0	0.95	1.03	1.02	0.95	1.04	1.04
Poland	2.6	2.21	1.99	1.81	2.22	2.03	1.87
Portugal	1.7	1.00	0.69	0.68	1.01	0.70	0.69
Romania	1.3	0.71	0.69	0.70	0.71	0.70	0.72
Slovakia	0.7	0.38	0.33	0.30	0.38	0.34	0.31
Slovenia	0.3	0.32	0.36	0.38	0.32	0.36	0.39
Spain	7.3	4.75	4.77	4.60	4.76	4.83	4.68
Sweden	1.8	1.35	1.52	1.47	1.35	1.53	1.49
UK	6.2	3.70	4.10	4.17	3.70	4.10	4.17
EU 27: Sum Road transport	70	38	38	37	38	38	37
EU 27: Sum all sectors	448	327	272	244	161	111	93

Table 6-10: OC emissions from non-road transport (SNAP sector 8) in all EU27 Member States in 2005 and in 2020, 2030 and 2050 according to the Baseline and the MTFR scenario, as well as EU27 totals.

OC SNAP 8: Non-road transport	kt 2005	*Draft Baseline Scenario* kt 2020	kt 2030	kt 2050	*Draft MTFR Scenario* kt 2020	kt 2030	kt 2050
Austria	0.56	0.21	0.08	0.06	0.21	0.08	0.05
Belgium	0.85	0.39	0.23	0.17	0.39	0.23	0.16
Bulgaria	0.27	0.10	0.04	0.02	0.10	0.04	0.02
Cyprus	0.04	0.01	0.01	0.01	0.01	0.01	0.01
Czech Republic	0.56	0.21	0.07	0.04	0.21	0.07	0.04
Denmark	1.16	0.41	0.23	0.19	0.41	0.22	0.19
Estonia	0.14	0.04	0.01	0.01	0.04	0.01	0.01
Finland	1.39	0.47	0.26	0.25	0.47	0.26	0.25
France	6.29	2.86	1.71	1.30	2.86	1.70	1.28
Germany	4.80	1.54	0.62	0.44	1.54	0.62	0.43
Greece	2.07	1.08	0.74	0.69	1.08	0.74	0.69
Hungary	0.35	0.12	0.03	0.01	0.12	0.03	0.01
Ireland	0.41	0.16	0.08	0.04	0.16	0.08	0.04
Italy	8.95	3.52	2.50	2.35	3.52	2.50	2.34
Latvia	0.11	0.06	0.01	0.01	0.06	0.01	0.01
Lithuania	0.12	0.08	0.03	0.01	0.08	0.03	0.01
Luxembourg	0.03	0.02	0.01	0.01	0.02	0.01	0.01
Malta	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	1.07	0.37	0.22	0.12	0.37	0.22	0.11
Poland	2.39	1.08	0.36	0.23	1.08	0.36	0.23
Portugal	0.53	0.24	0.15	0.13	0.24	0.15	0.13
Romania	0.68	0.50	0.30	0.10	0.50	0.29	0.09
Slovakia	0.08	0.03	0.02	0.01	0.03	0.02	0.01
Slovenia	0.15	0.06	0.02	0.02	0.06	0.02	0.02
Spain	5.29	1.91	0.74	0.57	1.90	0.74	0.56
Sweden	1.72	0.44	0.34	0.34	0.44	0.34	0.34
UK	4.80	2.10	1.05	1.04	2.10	1.05	1.04
EU 27: Sum Non-road transport	45	18	10	8	18	10	8
EU 27: Sum all sectors	448	327	272	244	161	111	93

Table 6-11: NMVOC emissions from road transport (SNAP sector 7) in all EU27 Member States in 2005 and in 2020, 2030 and 2050 according to the Baseline and the MTFR scenario, as well as EU27 totals.

		Draft Baseline Scenario			*Draft MTFR Scenario*		
NMVOC	kt	kt	kt	kt	kt	kt	kt
SNAP 7: Road transport	2005	2020	2030	2050	2020	2030	2050
Austria	31	8.5	7.5	7.7	8.6	7.5	7.7
Belgium	40	7.8	7.6	8.3	7.9	7.6	8.3
Bulgaria	49	9.7	14.3	6.0	9.7	14.3	6.0
Cyprus	5	1.5	1.1	1.0	1.5	1.1	1.0
Czech Republic	98	30.9	19.3	14.7	30.9	19.3	14.7
Denmark	30	6.0	4.7	4.6	6.0	4.7	4.6
Estonia	7	2.0	1.2	1.0	2.0	1.2	1.0
Finland	40	6.2	5.0	3.9	6.2	5.0	3.9
France	262	51.6	46.0	47.9	51.7	46.0	47.9
Germany	238	62.3	52.2	49.0	62.4	52.2	49.0
Greece	137	42.1	23.9	21.7	42.1	23.9	21.7
Hungary	51	17.2	10.4	7.6	17.2	10.4	7.6
Ireland	20	9.5	7.0	7.3	9.5	7.0	7.3
Italy	407	100.8	81.7	74.4	100.9	81.8	74.4
Latvia	13	4.3	2.2	1.8	4.4	2.2	1.8
Lithuania	16	5.6	3.4	2.9	5.6	3.4	2.9
Luxembourg	10	2.2	1.9	1.9	2.2	1.9	1.9
Malta	1	0.2	0.2	0.2	0.2	0.2	0.2
Netherlands	75	15.4	14.5	14.5	15.4	14.5	14.5
Poland	166	59.4	34.1	27.8	59.4	34.1	27.8
Portugal	51	14.0	9.7	8.5	14.0	9.7	8.5
Romania	92	19.7	9.9	8.5	19.7	9.9	8.5
Slovakia	22	7.7	3.8	3.0	7.7	3.8	3.0
Slovenia	12	2.5	2.0	1.8	2.5	2.0	1.8
Spain	188	42.4	40.1	40.7	42.5	40.1	40.7
Sweden	57	10.8	8.4	8.0	10.9	8.4	8.0
UK	153	51.4	47.9	48.0	51.4	47.9	48.0
EU 27: Sum Road transport	2271	592	460	422	592	460	422
EU 27: Sum all sectors	9535	6249	5797	5617	4091	3726	3587

Table 6-12: NMVOC emissions from non-road transport (SNAP sector 8) in all EU27 Member States in 2005 and in 2020, 2030 and 2050 according to the Baseline and the MTFR scenario, as well as EU27 totals.

		Draft Baseline Scenario			*Draft MTFR Scenario*		
NMVOC	kt	kt	kt	kt	kt	kt	kt
SNAP 8: Non-road transport	2005	2020	2030	2050	2020	2030	2050
Austria	6.20	4.95	3.99	3.98	4.89	3.38	3.03
Belgium	14.51	6.75	4.83	4.63	6.70	4.32	3.72
Bulgaria	2.23	1.41	1.11	1.06	1.38	0.81	0.61
Cyprus	0.48	0.41	0.43	0.50	0.40	0.34	0.36
Czech Republic	7.24	3.92	2.63	2.50	3.87	2.16	1.74
Denmark	21.14	8.17	5.81	5.63	8.10	5.11	4.47
Estonia	1.26	0.49	0.27	0.25	0.49	0.21	0.17
Finland	28.32	12.18	7.00	7.09	12.12	6.40	6.14
France	91.35	45.87	33.30	32.42	45.43	28.94	25.13
Germany	60.99	36.68	28.31	28.31	36.36	25.66	23.69
Greece	29.36	13.37	9.45	9.36	13.25	8.21	7.49
Hungary	2.97	1.58	0.98	0.96	1.56	0.76	0.62
Ireland	2.84	1.87	1.56	1.45	1.84	1.22	0.86
Italy	167.5	49.23	35.89	35.43	48.85	32.21	29.52
Latvia	1.32	0.86	0.64	0.83	0.86	0.62	0.80
Lithuania	1.23	0.93	0.70	0.69	0.92	0.56	0.34
Luxembourg	0.47	0.48	0.42	0.42	0.48	0.36	0.33
Malta	0.05	0.08	0.10	0.11	0.08	0.09	0.11
Netherlands	10.93	6.61	5.71	5.06	6.52	4.69	2.88
Poland	39.72	22.16	14.68	14.19	21.74	10.52	7.62
Portugal	7.48	4.18	3.17	3.20	4.14	2.74	2.48
Romania	8.62	5.63	4.01	3.39	5.57	3.44	1.91
Slovakia	1.15	0.55	0.40	0.37	0.54	0.35	0.25
Slovenia	1.98	1.51	1.22	1.21	1.48	1.02	0.93
Spain	55.51	27.32	18.10	18.00	26.84	13.29	10.30
Sweden	34.56	10.76	9.83	9.89	10.71	9.38	9.25
UK	56.81	37.11	28.71	28.77	36.64	24.01	22.39
EU 27: Sum Non-road transport	656	305	223	220	302	191	167
EU 27: Sum all sectors	9535	6250	5797	5617	4091	3726	3587

Table 6-13: CO emissions from road transport (SNAP sector 7) in all EU27 Member States in 2005 and in 2020, 2030 and 2050 according to the Baseline and the MTFR scenario, as well as EU27 totals.

		Draft Baseline Scenario			*Draft MTFR Scenario*		
CO	kt	kt	kt	kt	kt	kt	kt
SNAP 7: Road transport	2005	2020	2030	2050	2020	2030	2050
Austria	197	57	48	47	57	48	47
Belgium	208	52	49	53	52	49	53
Bulgaria	208	42	56	23	42	56	23
Cyprus	21	7	5	5	7	5	5
Czech Republic	438	116	73	70	116	73	70
Denmark	192	47	33	32	47	33	32
Estonia	44	15	9	8	15	9	8
Finland	255	55	45	41	55	45	41
France	1245	267	238	248	267	238	248
Germany	1664	439	333	308	439	333	308
Greece	573	204	112	99	204	112	99
Hungary	194	65	49	46	65	49	46
Ireland	158	77	62	67	77	62	67
Italy	1960	496	399	375	496	399	375
Latvia	61	22	11	9	22	11	9
Lithuania	76	25	15	12	25	15	12
Luxembourg	50	13	12	12	13	12	12
Malta	5	1.0	0.9	0.9	1.0	0.9	0.9
Netherlands	422	104	92	92	104	92	92
Poland	873	320	172	142	320	172	142
Portugal	181	58	47	49	58	47	49
Romania	441	102	53	48	102	54	48
Slovakia	100	38	21	18	38	21	18
Slovenia	74	19	15	13	19	15	13
Spain	914	249	230	233	249	230	233
Sweden	328	75	57	54	75	57	54
UK	1547	453	413	415	453	413	415
EU 27: Sum Road transport	12429	3420	2650	2521	3421	2651	2521
EU 27: Sum all sectors	27075	15852	13627	13152	11518	9500	9144

Table 6-14: CO emissions from non-road transport (SNAP sector 8) in all EU27 Member States in 2005 and in 2020, 2030 and 2050 according to the Baseline and the MTFR scenario, as well as EU27 totals.

CO SNAP 8: Non-road transport	kt 2005	*Draft Baseline Scenario* kt 2020	kt 2030	kt 2050	*Draft MTFR Scenario* kt 2020	kt 2030	kt 2050
Austria	49.0	36.1	29.1	28.8	36.1	29.1	28.8
Belgium	51.0	20.6	9.6	9.0	20.6	9.6	9.0
Bulgaria	4.2	2.4	1.7	1.5	2.4	1.7	1.5
Cyprus	0.7	0.4	0.3	0.3	0.4	0.3	0.3
Czech Republic	36.6	18.4	7.4	6.9	18.4	7.4	6.9
Denmark	168.5	51.6	31.1	22.8	51.6	31.1	22.8
Estonia	2.2	0.8	0.4	0.3	0.8	0.4	0.3
Finland	82.5	112.7	15.3	15.0	112.7	15.3	15.0
France	326.9	139.7	106.9	104.2	139.7	106.9	104.2
Germany	383.6	232.3	177.0	174.9	232.3	177.0	174.9
Greece	52.9	26.5	19.4	18.6	26.5	19.4	18.6
Hungary	5.4	2.5	1.3	1.1	2.5	1.3	1.1
Ireland	5.0	2.8	2.0	1.7	2.8	2.0	1.7
Italy	381.4	286.5	263.4	261.8	286.5	263.4	261.8
Latvia	1.8	1.0	0.3	0.3	1.0	0.3	0.3
Lithuania	1.9	1.3	0.9	0.7	1.3	0.9	0.7
Luxembourg	0.4	0.3	0.2	0.2	0.3	0.2	0.2
Malta	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Netherlands	19.7	11.2	8.7	6.8	11.2	8.7	6.8
Poland	58.4	29.8	18.1	16.4	29.8	18.1	16.4
Portugal	68.2	26.4	10.9	10.4	26.4	10.9	10.4
Romania	14.1	8.7	5.9	5.0	8.7	5.9	5.0
Slovakia	1.8	0.7	0.5	0.4	0.7	0.5	0.4
Slovenia	15.7	23.2	22.6	22.5	23.2	22.6	22.5
Spain	101.2	52.5	31.2	29.9	52.5	31.2	29.9
Sweden	157.5	115.8	156.5	156.5	115.8	156.5	156.5
UK	356.6	343.9	316.1	316.4	343.9	316.1	316.4
EU 27: Sum Non-road transport	2347	1548	1237	1212	1548	1237	1212
EU 27: Sum all sectors	27075	15852	13627	13152	11518	9500	9144

Table 6-15: SO_2 emissions from road transport (SNAP sector 7) in all EU27 Member States in 2005 and in 2020, 2030 and 2050 according to the Baseline and the MTFR scenario, as well as EU27 totals.

		Draft Baseline Scenario			*Draft MTFR Scenario*		
SO_2	kt	kt	kt	kt	kt	kt	kt
SNAP 7: Road transport	2005	2020	2030	2050	2020	2030	2050
Austria	0.56	0.13	0.12	0.12	0.13	0.12	0.12
Belgium	0.70	0.15	0.14	0.15	0.15	0.14	0.15
Bulgaria	1.35	0.13	0.15	0.16	0.13	0.15	0.16
Cyprus	0.37	0.01	0.01	0.01	0.01	0.01	0.01
Czech Republic	1.03	0.13	0.13	0.13	0.13	0.13	0.13
Denmark	0.08	0.07	0.06	0.06	0.07	0.06	0.06
Estonia	0.62	0.01	0.01	0.02	0.01	0.01	0.02
Finland	0.08	0.07	0.06	0.06	0.07	0.06	0.06
France	4.08	0.77	0.73	0.75	0.77	0.73	0.75
Germany	4.96	0.95	0.83	0.77	0.95	0.83	0.77
Greece	0.47	0.12	0.11	0.11	0.12	0.11	0.11
Hungary	1.29	0.10	0.10	0.10	0.10	0.10	0.10
Ireland	0.47	0.09	0.09	0.10	0.09	0.09	0.10
Italy	2.72	0.70	0.70	0.70	0.70	0.70	0.70
Latvia	0.10	0.02	0.03	0.03	0.03	0.03	0.03
Lithuania	2.82	0.03	0.03	0.03	0.03	0.03	0.03
Luxembourg	0.04	0.05	0.05	0.04	0.05	0.05	0.04
Malta	0.16	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	0.70	0.19	0.18	0.18	0.19	0.18	0.18
Poland	0.89	0.31	0.33	0.33	0.31	0.33	0.33
Portugal	0.64	0.12	0.12	0.12	0.12	0.12	0.12
Romania	1.28	0.12	0.13	0.14	0.12	0.13	0.14
Slovakia	1.02	0.05	0.05	0.04	0.05	0.05	0.04
Slovenia	0.48	0.05	0.05	0.05	0.05	0.05	0.05
Spain	2.67	0.73	0.73	0.71	0.73	0.73	0.71
Sweden	0.14	0.14	0.12	0.12	0.14	0.12	0.12
UK	2.81	0.69	0.65	0.66	0.69	0.65	0.66
EU 27: Sum Road transport	33	5.9	5.7	5.7	5.9	5.7	5.7
EU 27: Sum all sectors	8133	2572	2224	1939	1655	1402	1165

Table 6-16: SO_2 emissions from non-road transport (SNAP sector 8) in all EU27 Member States in 2005 and in 2020, 2030 and 2050 according to the Baseline and the MTFR scenario, as well as EU27 totals.

		Draft Baseline Scenario			*Draft MTFR Scenario*		
SO_2	kt	kt	kt	kt	kt	kt	kt
SNAP 8: Non-road transport	2005	2020	2030	2050	2020	2030	2050
Austria	0.14	0.13	0.15	0.16	0.13	0.15	0.16
Belgium	2.26	1.04	1.03	1.05	1.04	1.03	1.05
Bulgaria	1.06	0.14	0.11	0.12	0.07	0.08	0.09
Cyprus	0.23	0.06	0.06	0.08	0.06	0.06	0.08
Czech Republic	0.44	0.08	0.10	0.11	0.08	0.10	0.11
Denmark	2.22	0.86	0.86	0.89	0.58	0.57	0.61
Estonia	0.29	0.03	0.03	0.03	0.02	0.02	0.03
Finland	1.16	0.95	0.96	0.98	0.84	0.85	0.87
France	23.89	4.00	2.61	2.61	1.89	1.82	1.83
Germany	1.76	1.46	1.43	1.45	1.46	1.43	1.45
Greece	23.83	20.32	5.73	5.79	4.99	5.03	5.09
Hungary	0.28	0.05	0.06	0.08	0.05	0.06	0.08
Ireland	1.72	1.60	0.59	0.62	0.55	0.59	0.62
Italy	54.36	57.18	15.32	15.33	13.21	13.48	13.49
Latvia	0.14	0.16	0.21	0.30	0.15	0.21	0.29
Lithuania	0.45	0.01	0.02	0.03	0.01	0.02	0.03
Luxembourg	0.05	0.06	0.06	0.06	0.06	0.06	0.06
Malta	0.01	0.02	0.02	0.02	0.02	0.02	0.02
Netherlands	3.88	0.71	0.70	0.72	0.53	0.52	0.54
Poland	2.22	0.72	0.75	0.79	0.72	0.75	0.79
Portugal	2.19	1.55	0.90	0.92	0.87	0.87	0.89
Romania	2.23	0.67	0.35	0.35	0.30	0.30	0.30
Slovakia	0.05	0.01	0.01	0.01	0.01	0.01	0.01
Slovenia	0.12	0.01	0.01	0.01	0.01	0.01	0.01
Spain	37.24	11.15	3.55	3.64	2.96	2.99	3.08
Sweden	2.11	0.88	0.90	0.94	0.73	0.75	0.79
UK	41.85	9.83	5.62	5.58	4.23	4.25	4.21
EU 27: Sum Non-road transport	206	114	42	43	36	36	37
EU 27: Sum all sectors	8133	2572	2224	1939	1655	1402	1165