

National and central estimates for air emissions from road transport

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Summary

High-quality estimates of national emissions of greenhouse gases and air pollutants are prerequisites for assessing compliance to the commitments made under the ratified protocols of international conventions. In addition, robust estimates of emissions are key to the analysis of the efficiency of national and regional policies for abatement measures.

This technical report covers assessment and evaluation of air emissions (CO₂, NO_x, VOC) from road transport within EU-15 during the period 1981–98 and projections to 2010–20. The report provides background information to transport emission indicators included in other main EEA reports published in 2001 (*Environmental signals 2001* (2) and 'TERM 2001' (3)) and in the topic report 'The ShAIR scenario' (4).

Main objectives

- To make a comparison between road transport emission estimates based on national data and on a centralised modelling methodology. The aim is to assess and investigate the difference in results between the two approaches as well as to propose measures which can increase the quality of the estimations.
- To present a comparison of three modelling approaches for projections of emissions from road transport (RAINS, Tremove and ForeMove/Copert). The aim is to assess differences in results and to identify the main factors causing these differences.
- To assess the effectiveness of various emission reduction measures for NO_x for EU-15 in the period 1980–2000, using a centralised methodology (ForeMove). In addition, the aim is to assess the robustness of the effectiveness assessment by comparing central estimates with national estimates.

Main conclusions

- A substantial decrease in emissions of air pollutants has taken place and is also projected up to 2010–20, while CO₂ emissions are projected to increase — largely due to increasing passenger car transport.
- The reduction in NO_x emissions during 1980–98 is primarily due to the introduction of three-way catalysts in new petrol-engine cars. A limited comparison, using national information and EU-wide models, of the effectiveness of abatement measures for NO_x emissions did not show significantly different results.
- The comparison between the central estimates and national data showed that the general trend of air emissions on EU-15 level were similar for both assessment methods but that comparisons at the national level often displayed differences.
- There are deviations between model projections based on top-down and bottom-up approaches respectively. Further comparison with national projections could contribute to clarify and mitigate these deviations.

Main recommendations

To improve the quality of central as well as national estimates, it is proposed:

- (a) to harmonise the definitions of model parameters;
- (b) to develop and apply methods to address data gaps;
- (c) to improve model calibration;
- (d) to increase understanding of model characteristics using sensitivity analysis;
- (e) to perform more in-depth comparisons with other central and national models;
- (f) to improve the statistical analysis of model estimates.

1. Introduction

Emissions of greenhouse gases and air pollutants are directly linked to environmental issues: climate change, acidification and eutrophication, and urban air quality. In response to the importance and transboundary characteristics of these environmental problems and their solutions, international bodies have established conventions and protocols stipulating agreed emission reductions for each party to the convention — individual countries as well as the European Community. The global convention addressing greenhouse gases is the United Nations Framework Convention on Climate Change (UNFCCC). The regional convention addressing air pollutants in Europe is the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP). In order to assess compliance with different protocols, e.g. distance to party specific targets, parties are required to submit annual reports on emission estimates for specific air pollutants and greenhouse gases.

Consistent, comparable, transparent, reliable and timely estimates of national emissions of greenhouse gases and air pollutants are prerequisites for assessing compliance to the commitments made under the ratified protocols of international conventions. Furthermore, robust estimates of emissions are key to the analysis of the efficiency of national and regional policies for abatement measures.

Emission estimates from all sources, including road transport, must be submitted in accordance with the agreed formats specified in the guidelines/guidebooks under the two main conventions mentioned above (see (1)). The quality of any emission estimate is dependent on the robustness of the data and methodologies used. A useful approach for improving quality in emission estimates is to make transparent comparisons between estimates based on different sets of data and methods. One useful approach is to compare national estimates — based on specific methodologies and national statistical transport and energy data — with estimates derived centrally. Central estimates are based on the same methodology and main assumptions for all countries and utilise data collected both from national sources and central databases. An advantage of central estimates is to facilitate the production of consistent emission estimates as well as emission projections, which may be used to assist in analysing policy efficiency on central level. A disadvantage of central estimates is that they are not specific enough to mirror the effect of specific national measures taken to alleviate environmental pressure from specific activities (e.g. tax incentives to encourage new cars). Thus, national and central estimates have different pros and cons when it comes to consistency and specificity, and national and central estimates often produce different results.

This technical report covers a comparison and analysis of national and central estimates of emissions from road transport including emissions projections for 2020, a comparison of three different models for projecting emissions and an analysis of the effectiveness of measures for reducing NO_x emissions from road transport. The report is based on information available to the EEA by the end of 2000. The report was produced as a technical reference to underpin information on emissions from road transport presented in other publications from the EEA during 2001: *Environmental signals 2001* (2), 'TERM 2001' (3) and 'The ShAIR scenario' topic report (4).

2. Objectives and scope

The objectives of the report are those listed below.

- To make a comparison between road transport emission estimates based on national data, provided by countries to the EEA, and on a centralised methodology, Copert III applied within the TERM (transport and environment reporting mechanism) (3). The comparison covers each Member State and EU-15 total for the pollutants CO₂, NO_x and VOC for the period 1981–98. The purpose of this comparison is to assess and investigate the difference in results between the two approaches as well as to propose measures which can increase the quality of the estimations.
- To use a central approach, ForeMove, to produce emission projections for EU-15 during the period 2000–20.
- To present the main findings of a comparison of three different modelling approaches to projecting emissions from road transport. The models are: RAINS (used for ‘The ShAIR scenario’ report (4)), Tremove (Auto-Oil II programme (5)) and the centralised ForeMove methodology — the ForeMove/Copert model. The main aim of this comparison is to assess differences in results and to identify the main factors causing these differences, with the long-term goal of achieving better comparability between the different models.
- To assess the effectiveness of various emission reduction measures, in terms of their effectiveness in reducing NO_x emissions from road transport, using the centralised ForeMove calculation methodology. In addition, the aim is to assess the robustness of the effectiveness assessment by comparing central estimates with national estimates.

3. Comparison and analysis of central and national emissions

3.1. Main difficulties in assessing emission estimates from road transport

It is difficult to collect consistent and comparable data at national level for reporting road transport related emissions because: (i) the accurate estimation of vehicle related emissions is a complex task involving a large number of different activity data, (ii) there is a large number of vehicle emission control technologies, and (iii) there are variable vehicle uses and different emission sources (exhaust emissions, fuel evaporation, wear, etc.). In addition, a time series of emissions is even more complex because extra- or interpolations may be necessary to compensate for missing data. Some of these difficulties are explored below in more detail.

The main problem in the collection of activity data is the lack of such data from national statistical sources. For example, vehicle-kilometres or passenger-kilometres data may be very poor for some vehicle types. A reason for this is the recurrent amendment of emission standards and the existence of several vehicle emission technologies in parallel. Furthermore, when more detailed data are required — e.g. mean trip length started with a cold engine, to estimate warming-up phase excess emissions — national statistical sources may not be adequate. In those cases, rough estimations from national experts might be required.

The estimate of emission levels also depends on the set of emission factors utilised by countries. Emission estimation can be based on nationally established tools and methods or other methodologies (e.g. Copert). The emission levels reported within the conventions are dependent on the methodological choices made at national level. Thus, deviations between national estimates may result from different methodological choices and not necessarily from actual differences in emissions.

For example, changes in activity data, assumptions and methods may affect the robustness and consistency of the time series of emission estimates. Therefore the reported time series need to be continuously updated using consistent sets of data and methods.

3.2. Nationally estimated and reported data

The core of national data used in this report consists of information made available by countries to the EEA by September 2000 (UNFCCC format and CLRTAP/Corinair format separately). This database (ETC/AE 2000 version 2) was used for the *Environmental signals 2001* and 'TERM 2001' reports and includes information on national emission estimates with regard to air pollutants (CO, NH₃, NMVOC, NO_x, SO₂) and greenhouse gases (CO₂, CH₄, N₂O, etc.) for the periods 1980–98 and 1990–98, respectively. Detailed information on the sources, handling and some adjustments of the initial data submitted by the countries are included in (2) and (3).

Since these data did not include a split for road transport emissions for CO₂, Eurostat estimates for the period 1985–98 have been used (derived from the New Cronos database).

3.3. The central approach ForeMove/Copert

The centralised–harmonised approach (ForeMove/Copert) for emissions and emission projections consists of two independent modules.

- The **vehicle dynamics module** is used to estimate the fleet population for each country. This module calculates the total vehicle fleet number per year in each country based on a Gompertz function. In a next step, the technology distribution of the fleet is calculated on the basis of a Weibull function taking into account rates of new vehicle registrations and vehicle removal from circulation. More information on this module may be found in MEET report (6).

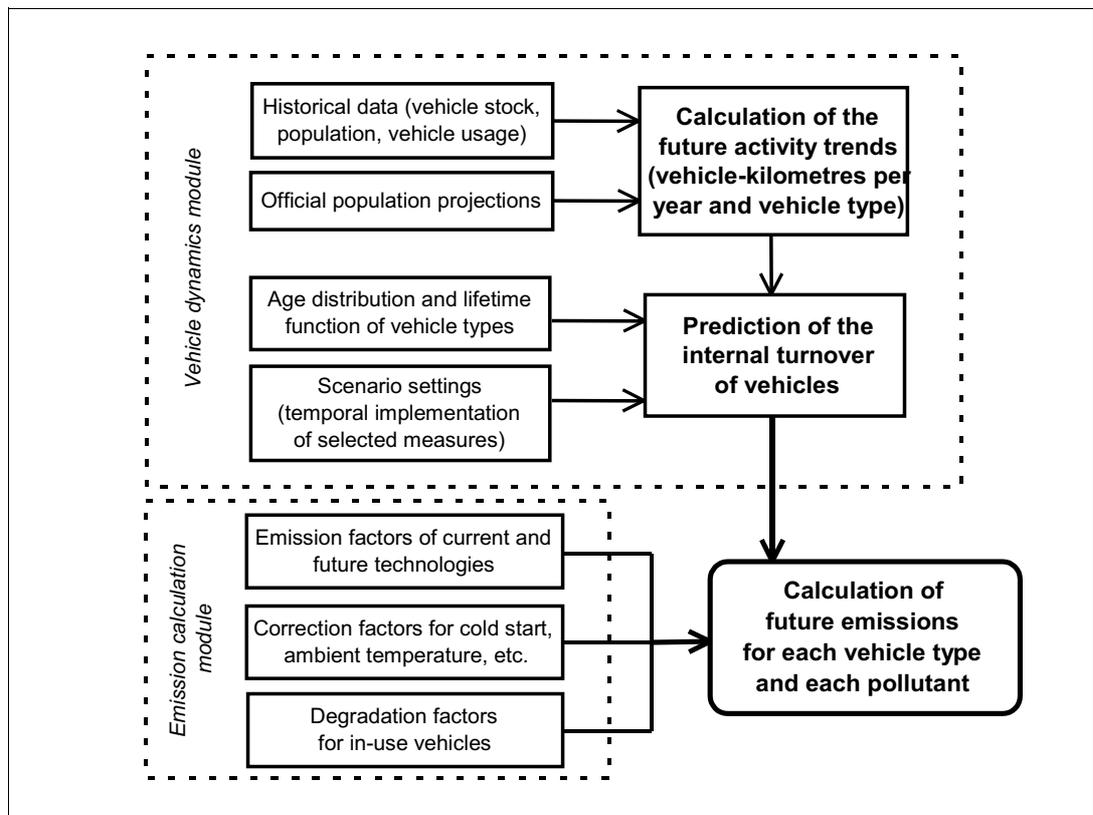
- The **emission calculation module** is used to estimate emission factors and total emissions. This is essentially the Copert II (7) model with the application of some amendments regarding the deterioration of emissions performance already included in the first version of Copert III (8).

With the exception of the Netherlands ⁽¹⁾, MEET data (6) have been used as input data for the centralised estimations. The remaining activity data (mean speeds per driving mode, mileage distribution, etc.) have been mainly obtained by former Copert exercises and correspond to national statistics. Those data are summarised by Kyriakis et al. (6). In addition, a number of updates brought in the calculations originate from the TRENDS report (9). Among them, the use of new shares for diesel passenger cars throughout the period 1981–98 (as these have been derived from the Eurostat database) is quoted.

Figure 1 summarises the calculation procedure. ForeMove includes the two abovementioned modules: the vehicle dynamics module and the Copert II/III tool for the calculation of total emissions on the basis of the estimated activity data. Emission estimates have been conducted on an annual basis for the period 1981–98 at national level, distinguished by urban, rural and highway driving. Emission projections for the period 2000–20 have been performed in five-year intervals and at a national level, also distinguished by the same three driving modes. The technology classes accounted for the emission projection calculations are shown in Table 1. These classes comply with the emission standards proposed in the latest Council directives, thus taking into account the introduction of up to Euro V vehicles; the latter are to be introduced in the European market in the year 2008. No post-Euro V vehicles were assumed to be introduced from the year 2008 onwards. It should also be noted that the ACEA commitment as regards the CO₂ emissions was not accounted for in the emission calculations.

Figure 1

Total calculation scheme (ForeMove/Copert (8), (10))



(1) For the Netherlands, emission calculations were performed on the basis of a new set of activity data for the period 1980–2000 (including fleet population, annual mileage, mean speeds per driving mode, mileage distribution, etc.) that was provided by RIVM. An assessment of the differences in emission estimates produced with the MEET and RIVM activity data is presented in Section 5.1.

3.4. The vehicle dynamics module

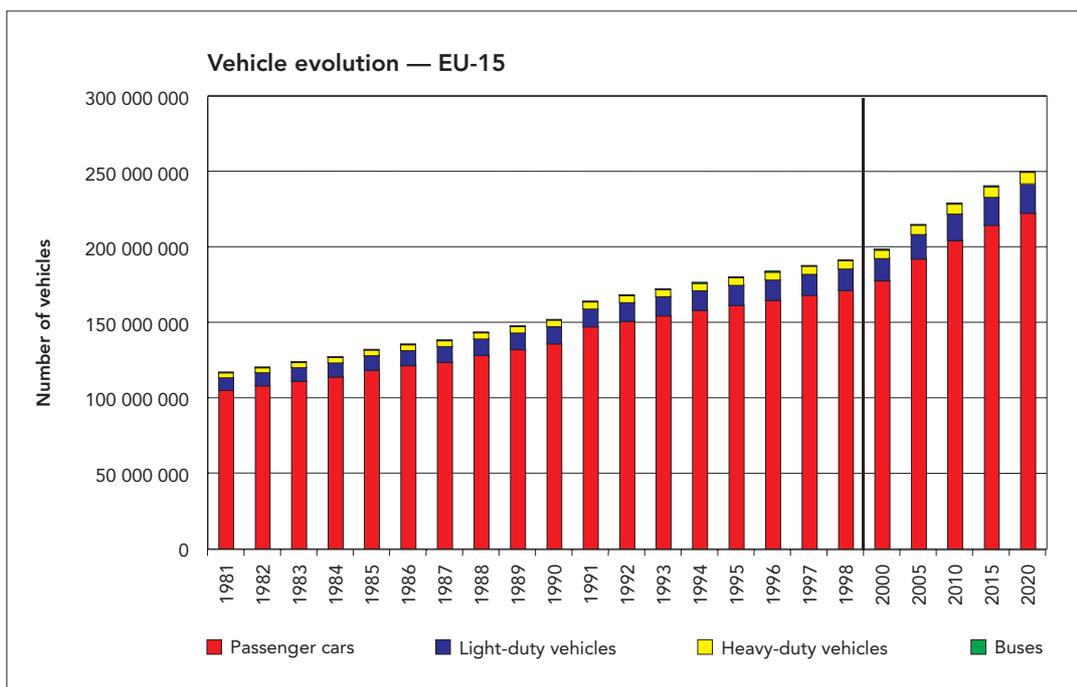
In this section, two parts of the vehicle dynamic module are explained in more detail.

3.4.1. Vehicle population data

In total, 15 different classes of motor vehicle categories are included in the calculations (seven classes of passenger cars, two classes of light commercial vehicles, four classes of heavy commercial vehicles and two classes of buses and coaches). As mentioned previously, MEET data (6) have been used as input for the centralised estimations. Based on the ForeMove methodology, the total number of vehicles in a country is estimated using a Gompertz saturation curve on the basis of measured data of previous years. The results of this approach are given in Figure 2 at EU-15 level and for all years examined. There is a small increase in 1991, which is due to the incorporation of the fleets of the former German Democratic Republic.

Number of vehicles in EU-15 in each category from 1981 to 2020

Figure 2



After calculating the total vehicle number, a simulation of the vehicle fleet turnover was performed in order to take into consideration the rate at which old vehicles are replaced by new ones. In this way, it was possible to estimate the mean age of the vehicles. The mean age of the vehicle is required as input information in order to simulate the deterioration of the vehicle emission performance because of the accumulated mileage (see Section 3.5). As an example, Figure 3 shows the mean age for passenger cars for all Member States for the year 1995.

Further processing of the data was carried out in order to adapt the total vehicle categories estimations produced by the vehicle dynamics module of ForeMove to the detailed vehicle classification structure required for application of the Copert methodology. Figure 4 provides an example of the passenger car fleet distribution to the various passenger car classes for year 1995.

Figure 3 Mean age of the passenger car fleet in 1995 for EU-15 Member States

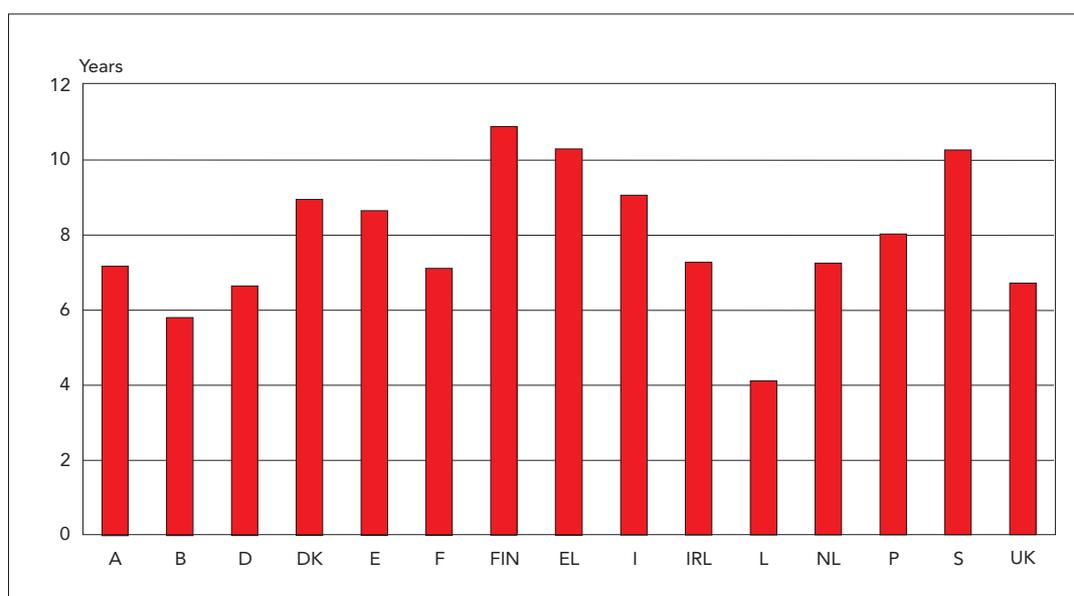
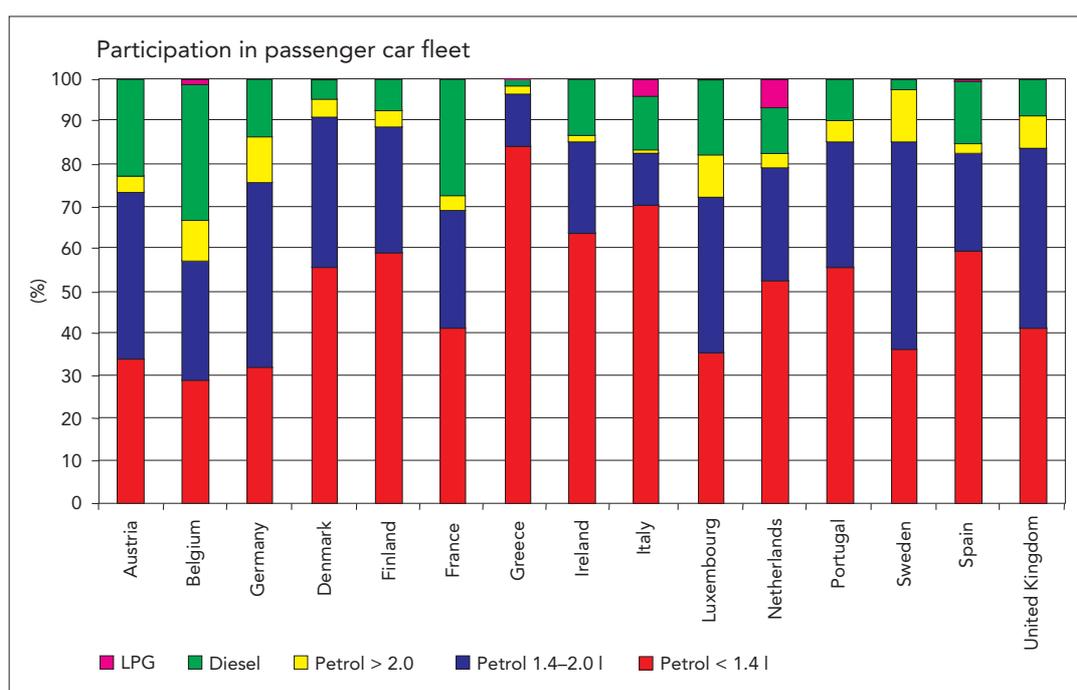


Figure 4 Passenger car fleet distribution across different vehicle classes in 1995 for EU-15 Member States



The implementation of new technology classes was also taken into consideration in order to include the technology factor of the emission behaviour of vehicles. The information was derived from knowledge of the emission legislation either already in force in the year of calculation or scheduled for the near future.

Table 1 provides the classification of the vehicle classes into different technology levels. The implementation year corresponds to the year for which the specific vehicle technology appears on the market for the first time. In accordance to the current or near future legislation with regard to vehicle emission standards, the technology classes shown in Table 1 reach up to Euro V. It should be noted that the emission standards upon which the vehicles are classified into different technology levels address only the so-called conventional pollutants; hence, neither emission standards for other pollutants (e.g. CO₂) nor future commitments/agreements (e.g. the ACEA commitment with regard to fuel specifications) are covered by the classification in Table 1.

Technology levels and implementation years assumed in the calculations

Table 1

Vehicle category	Impl. year	Vehicle category	Impl. year
Petrol PCs <1.4 l		2-stroke PCs	
Pre-ECE	pre-1981	Petrol LDVs <3.5 t	
ECE 15/00-01	pre-1981	Conventional	pre-1995
ECE 15/02	pre-1981	Euro I (93/59/EEC)	1995
ECE 15/03	1981	Euro II (96/69/EC)	1998
ECE 15/04	1985	Euro III	2002
Improved conventional	1986	Euro IV	2007
Open loop	1986	Diesel LDVs <3.5 t	
Euro I (national — 91/441/EEC)	1986–93 (1)	Conventional	pre-1995
Euro II	1996	Euro I (93/59/EEC)	1995
Euro III	2001	Euro II (96/69/EC)	1998
Euro IV	2006	Euro III	2002
		Euro IV	2007
Petrol PCs 1.4 — 2.0 l		Diesel HDVs 3.5–7.5 t	
Pre-ECE	pre-1981	Conventional	pre-1995
ECE 15/00-01	pre-1981	Euro I (91/542/EE, stage 1)	1995
ECE 15/02	pre-1981	Euro II (91/542/EE, stage 2)	1998
ECE 15/03	1981	Euro III	2002
ECE 15/04	1985	Euro IV	2005
Improved conventional	1986	Euro V	2008
Open loop	1986	Diesel HDVs 7.5 — 16 t	
Euro I (national — 91/441/EEC)	1986–93	Conventional	pre-1995
Euro II	1996	Euro I (91/542/EEC, stage 1)	1995
Euro III	2001	Euro II (91/542/EEC, stage 1)	1998
Euro IV	2006	Euro III	2002
		Euro IV	2005
		Euro V	2008
Petrol PCs >2.0 l		Diesel HDVs 16 — 32 t	
Pre-ECE	pre-1981	Conventional	pre-1995
ECE 15/00-01	pre-1981	Euro I (91/542/EEC, stage 1)	1995
ECE 15/02	pre-1981	Euro II (91/542/EEC, stage 1)	1998
ECE 15/03	1981	Euro III	2002
ECE 15/04	1985	Euro IV	2005
Euro I (national — 91/441/EEC)	1986–93	Euro V	2008
Euro II	1996		
Euro III	2001		
Euro IV	2006		
Diesel PCs <2.0 l		Diesel HDVs >32 t	
Conventional	pre-1986	Conventional	pre-1995
Euro I (national — 91/441/EEC)	1986–91	Euro I (91/542/EEC, stage 1)	1995
Euro II	1997	Euro II (91/542/EEC, stage 1)	1998
Euro III	2001	Euro III	2002
Euro IV	2006	Euro IV	2005
		Euro V	2008
Diesel PCs >2.0 l		Buses-coaches	
Conventional	pre-1986	Conventional	pre-1993
Euro I (national — 91/441/EEC)	1986–93	Euro I (91/542/EEC, stage 1)	1993
Euro II	1997	Euro II (91/542/EEC, stage 1)	1997
Euro III	2001	Euro III	2002
Euro IV	2006	Euro IV	2005
		Euro V	2008
LPG PCs			
Conventional	pre-1986		
Euro I	1986–93		
Euro II	1997		
Euro III	2001		
Euro IV	2006		

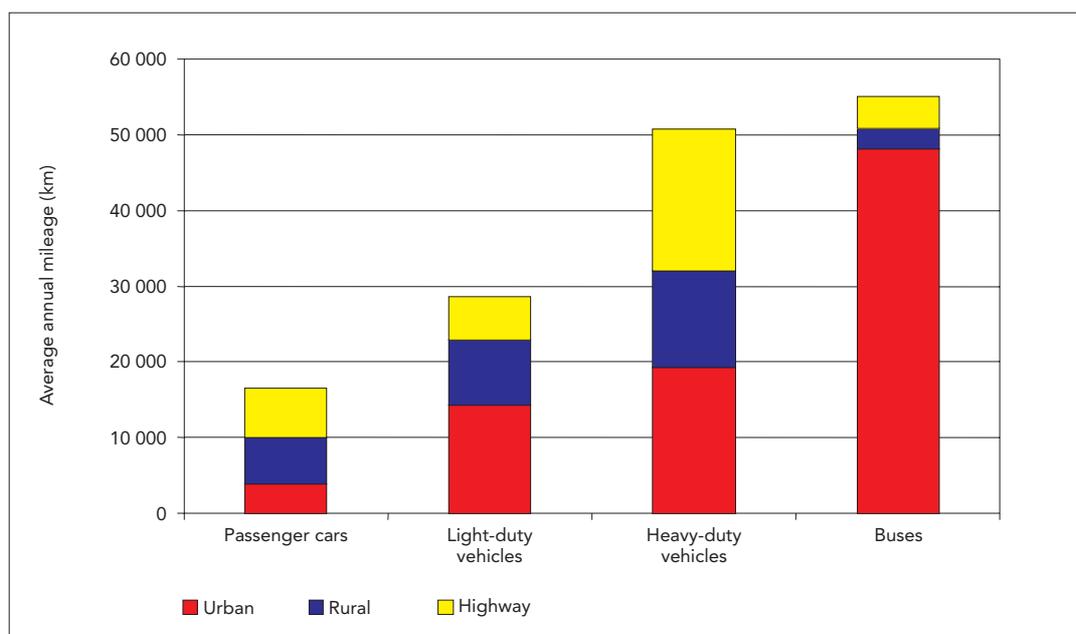
1) The listing of more than one implementation year shows that the introduction of this technology has come into effect at different years in different European countries mainly due to national incentives taken before the implementation date of the common European Directive 91/441/EEC, which came into effect in 1993.

3.4.2. Vehicle use data

Fleet population data is combined with data on the use of vehicles to produce total emission estimates. The vehicle-use data necessary are: average travelling speeds, the mean annual mileage driven and the distribution of this mileage to different driving modes. As previously mentioned, data collected in the framework of older Copert exercises, summarised in (6), have been used in this report. Figure 5 shows as an example the average 1995 mileage driven by each category of vehicle in the Netherlands, distinguished into the three main driving modes (urban, rural, highway).

Figure 5

Average 1995 mileage per vehicle category in the Netherlands

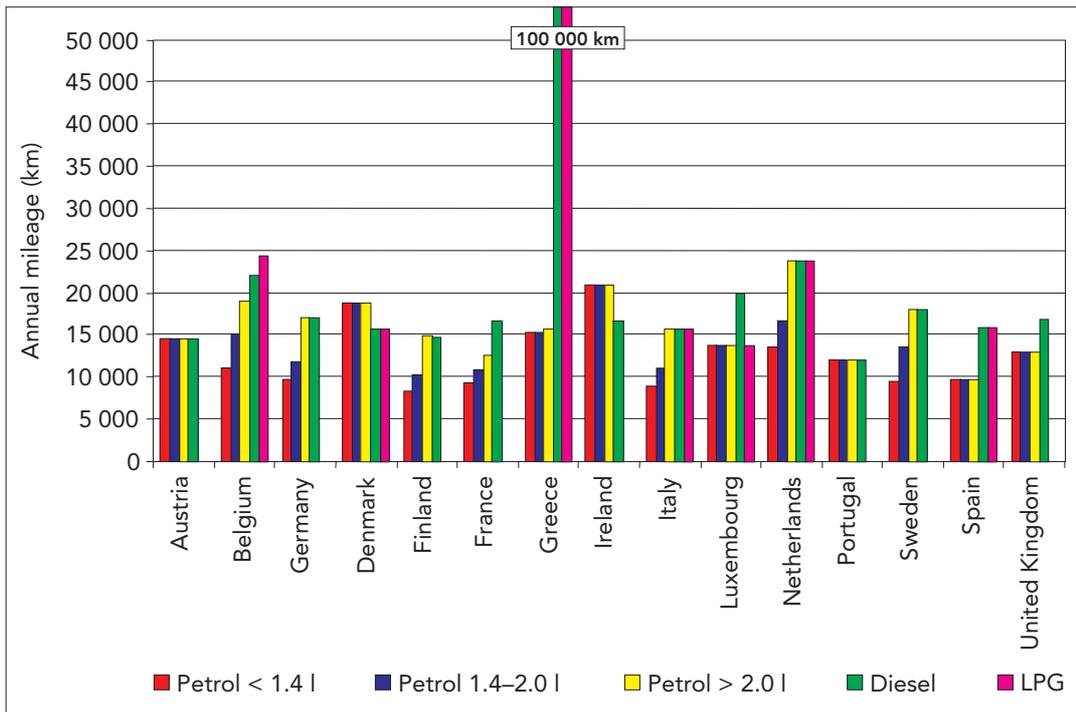


In addition to vehicle category, vehicle class also has an influence on the mileage driven per year. Figure 6 shows the dependence of mileage on the engine capacity and fuel use of passenger cars. Where detailed statistical data exist, mileage driven increases with engine capacity probably due to the fact that larger vehicles are usually driven more. Another general trend is that annual mileage is higher for diesel vehicles. As a result, the distinction of mileage driven according to vehicle class needs to be addressed.

Using the fleet population and mileage driven per vehicle category and driving mode, the total vehicle-kilometres can be calculated (Figure 7). Passenger cars dominate the total number of vehicle-kilometres while buses make the smallest contribution. As expected, the driving modes are different for different vehicle categories, e.g. buses are driven mostly in urban conditions. The time series for passenger cars and light commercial vehicles illustrates the increasing annual vehicle-kilometres per vehicle category.

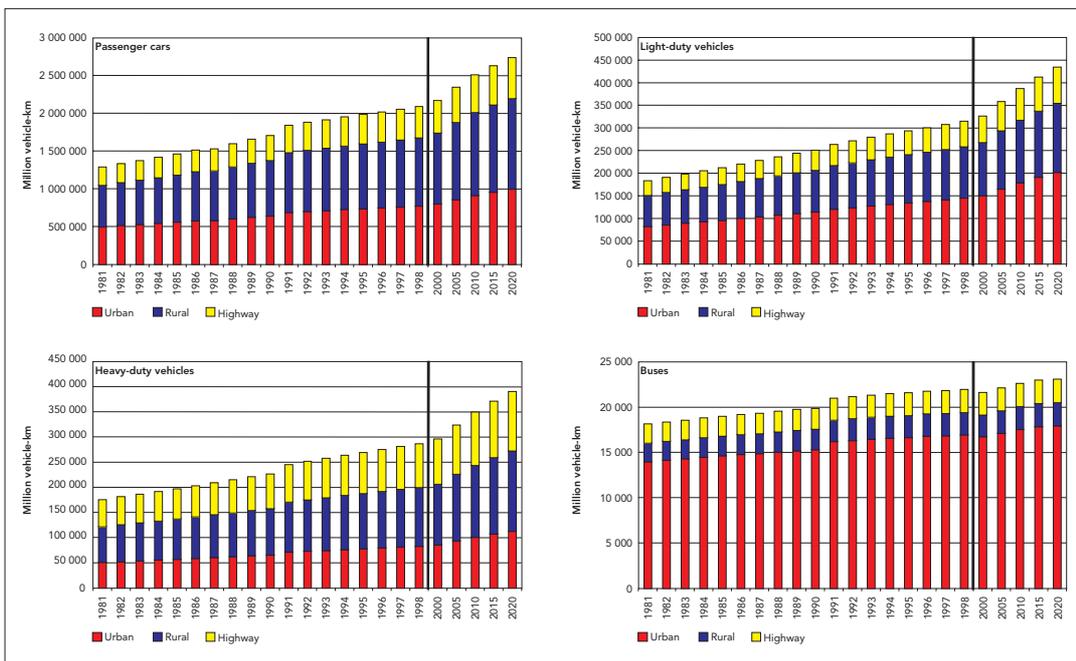
Engine type and size effect on annual mileage of passenger cars in EU-15 in 1995

Figure 6



Estimations of total annual vehicle-kilometres driven per vehicle category and driving mode per year

Figure 7



3.5. The emission calculation module

The calculation of total annual emissions is performed with Copert II. All emission factor functions, evaporation modelling and cold start have been applied according to Copert II methodology up to Euro I technology level. However, in order to better implement the effect of the more recent vehicle technologies and the degradation of the emission performance with age, some of the methodological updates launched in Copert III have also been implemented in this project. Those updates are explained in the following paragraphs.

Experimental, measured data for the development of emission factors only exist up to the Euro I level and have been summarised in the MEET final report (11). However, emission factors for more recent and future vehicle technologies (Euro II–IV) were included in the model, using reduction factors to the emission level of Euro I vehicles. The reduction factors were based on the evolution of the emission standards for the specific vehicle technologies. Copert III includes reduction factors up to Euro IV for all vehicle categories considered in the framework of this exercise. These reduction factors have been introduced in the calculations for this report.

A Copert III approach was also used to simulate the degradation of vehicle emission performance as a function of the accumulated mileage. Several parameters affect the relationship between emission performance and accumulated mileage, for example: the ageing of the catalyst, the deterioration of the engine-out emissions due to deposit build-up in the engine, engine wear.

For reporting time-series, the relationship between accumulated mileage and deteriorated emission performance is particularly important. To include this in the calculations, this feature was used from Copert III.

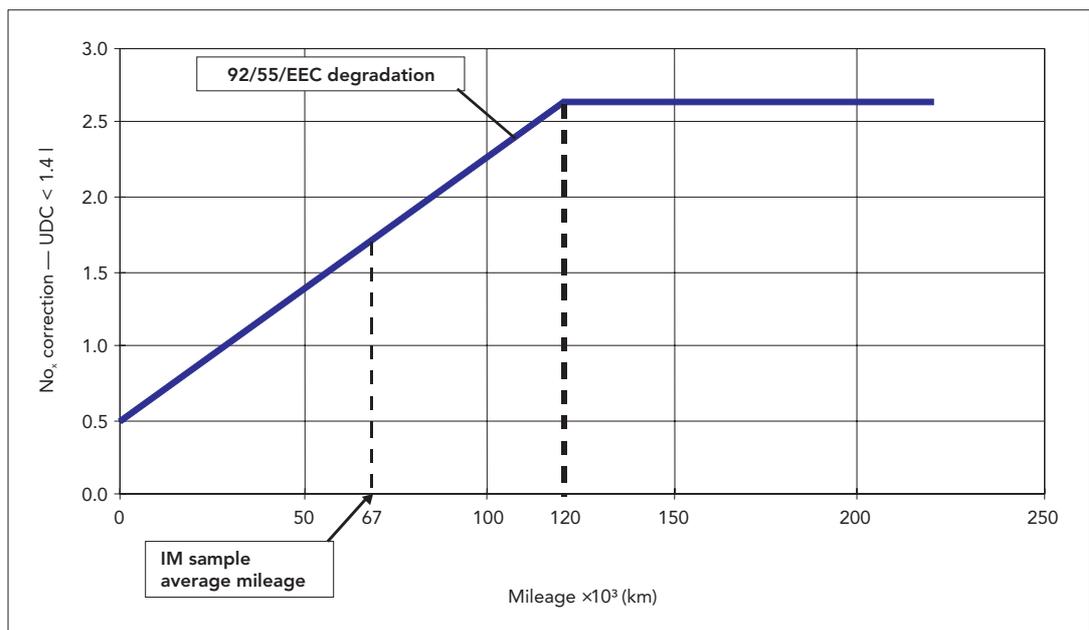
The technical details of simulating degradation in emission performance are not included in this report. Further reading may be found in (12). The generic relationship between accumulated mileage and deteriorated emission performance is modelled according to the example presented in Figure 8. Thus, the model assumes that the emission performance deteriorates gradually with increased mileage up to some point and then stabilises because of maintenance practice, i.e. engine component repairs, catalyst replacement, etc. Similar models have been produced and used for all combinations of pollutants, vehicle classes and speed ranges for this report.

In the case of conventional vehicles, i.e. non-catalyst equipped, the absence of catalysts reduces the effect of mileage accumulation on emissions. Furthermore, no deterioration of the emission performance has been applied for conventional vehicles because of lacking experimental data.

For cold-start-related emissions, Copert II was modified to better reflect some more recent experimental data available through MEET.

Figure 8

Modelling of emission level deterioration as a function of accumulated mileage (example given refers to NO_x emissions, petrol Euro I passenger cars, engine capacity < 1.4 l and for speeds ≤ 19 km/h)



The impact of improved petrol and diesel fuel which will be introduced on the market in two stages until the year 2005 ⁽²⁾ was accounted for by adjusting the emission factors of earlier catalyst vehicles. Thus, emission factors were adjusted first for the period 2000–05 when stage 1 fuel will be used and then for the post-2005 period, after the introduction of stage 2 fuel. The adjustment is based on the relation between fuel specifications and exhaust emissions, which have been produced within the framework of the European programme on emissions, fuels and engine technologies (EPEFE) (13).

It should also be noted that mainly exhaust VOC emissions were calculated. Evaporation losses were only estimated for five-year intervals during the period examined.

3.6. Main results from comparing central and national emission estimates

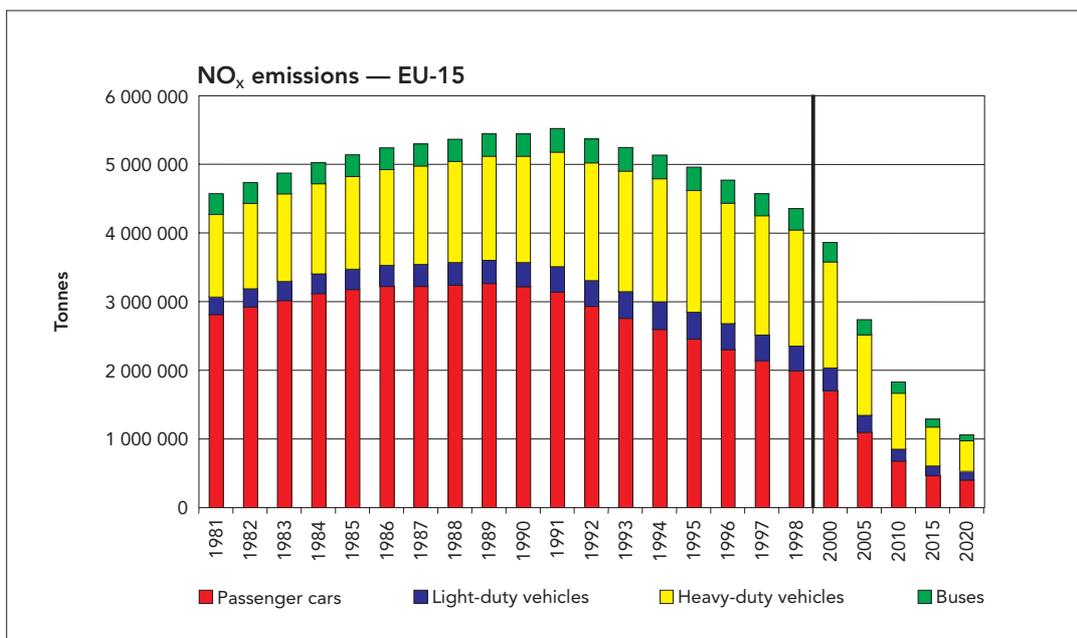
In this section the results presented refer to EU-15 totals. The input data and emission results for individual Member States are presented in the annex to the report. Two graphs are presented per pollutant. The first displays results from centralised estimations/projection using ForeMove/Copert and provide the contribution of the different vehicle categories to the total emissions. The first graph shows projected emissions until year 2020. The second graph displays a comparison between the centralised approach and the estimates based on the national activity data. The comparison is made for results for years 1981 to 1998, which is the last year for which national activity data is reported.

3.6.1. NO_x emissions

Emissions of nitrogen oxides increased steadily during the 1980s with approximately 20 % due to increasing road traffic. From 1991 to 1998 NO_x emissions have decreased by 20 % in EU Member States mainly due to the introduction of three-way catalysts on new passenger cars. HDVs also contributed to the decrease from the mid-1990s, but to a smaller extent. The emissions from LDVs and buses show no clear trend up to 1998, as emission standards for these vehicles were very mild until that time. The implementation of stringent measures through the 1999 directives, on the other hand, is expected to significantly reduce NO_x emissions from 2000 onwards.

EU-15 — Total NO_x emissions and contribution of different vehicle categories according to centralised estimates (LAT)

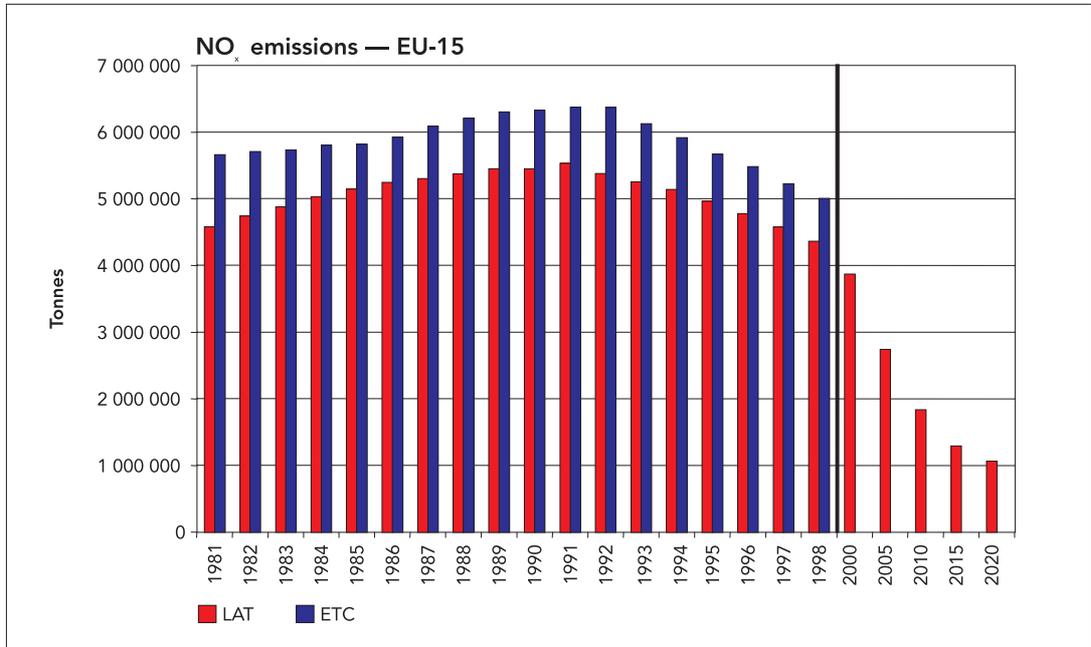
Figure 9



(2) New fuels will be introduced in two stages. Stage 1 fuel, which appeared in 2000, enabled the implementation of Euro III emission standards, while stage 2 fuel will be made available in 2005, enabling the implementation of Euro IV. As regards petrol, the new fuels will have lower sulphur, aromatics and benzene content, and some oxygenates. Diesel fuels will have a significantly lower sulphur content and also a decreased total aromatics content.

At EU-15 level, the central estimates (LAT) are in the range of 10–20 % higher than national estimates (ETC) (Figure 10). However, comparison of results at national level shows that for some countries central estimates are systematically higher or lower for the whole of the period investigated. For some countries there is no clear trend on which method yields the highest/lowest estimates (see annex).

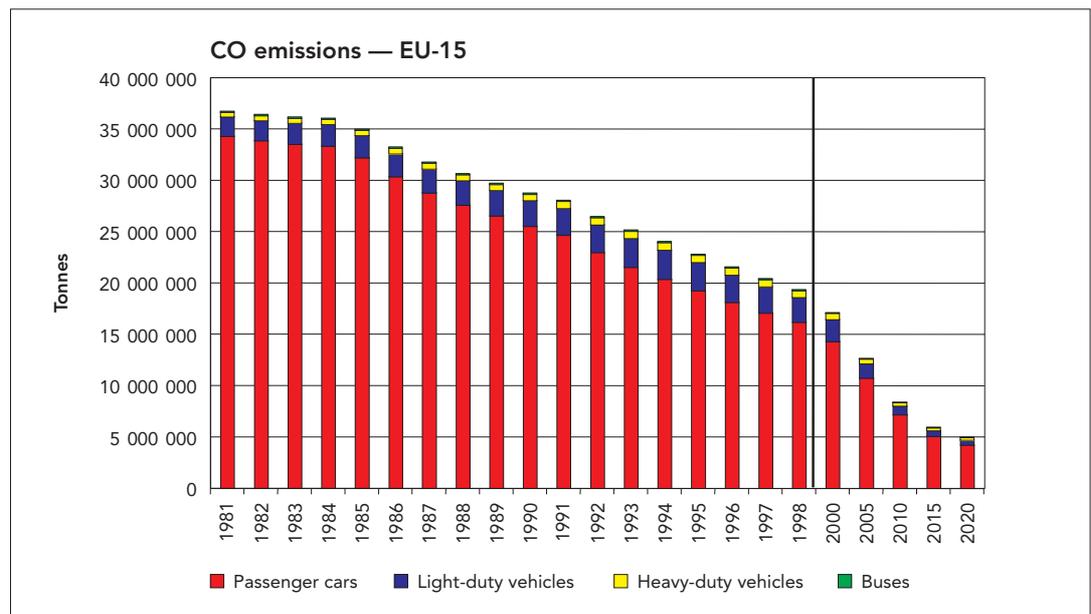
Figure 10 Comparison of centralised NO_x estimates (LAT) with national data (ETC)



3.6.2. CO emissions

The results for CO emissions show that there is a general decrease of CO emission levels from 1981 to 1998 (Figure 11). The projections indicate that the decrease is expected to continue.

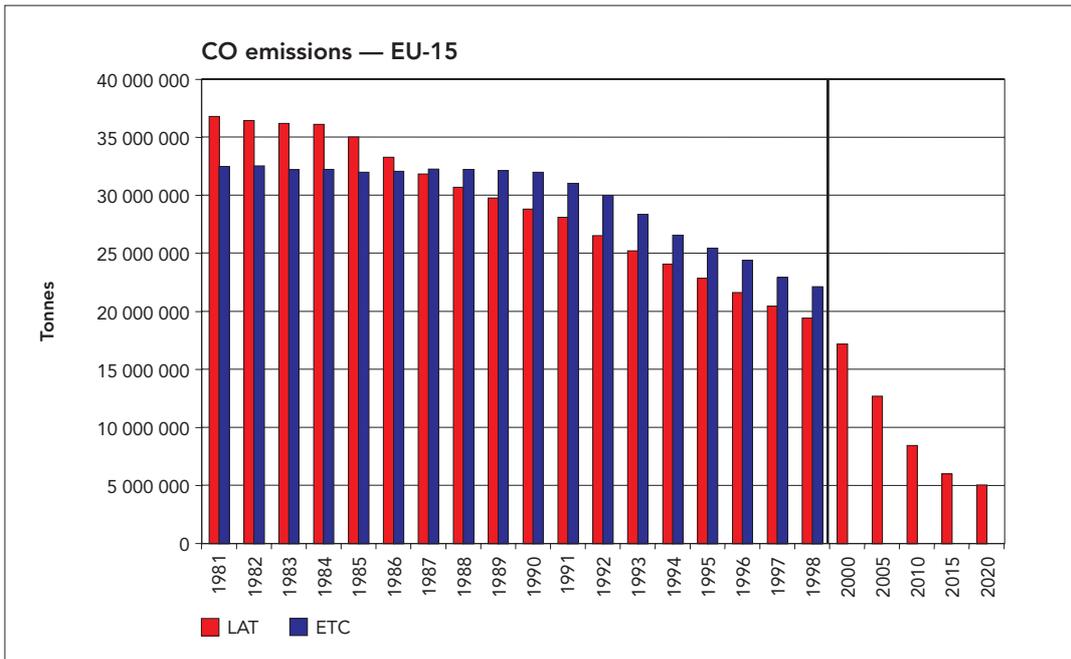
Figure 11 EU-15 — Total CO emissions and contribution of different vehicle categories according to centralised estimates (LAT)



Comparing central and national estimates at EU-15 level shows that it is not possible to make unambiguous statements on which of the methods produces the highest/lowest estimates. The difference between the estimates is generally relatively small. However, differences can be larger at national level (see annex).

Comparison of centralised CO estimates (LAT) with national data (ETC)

Figure 12

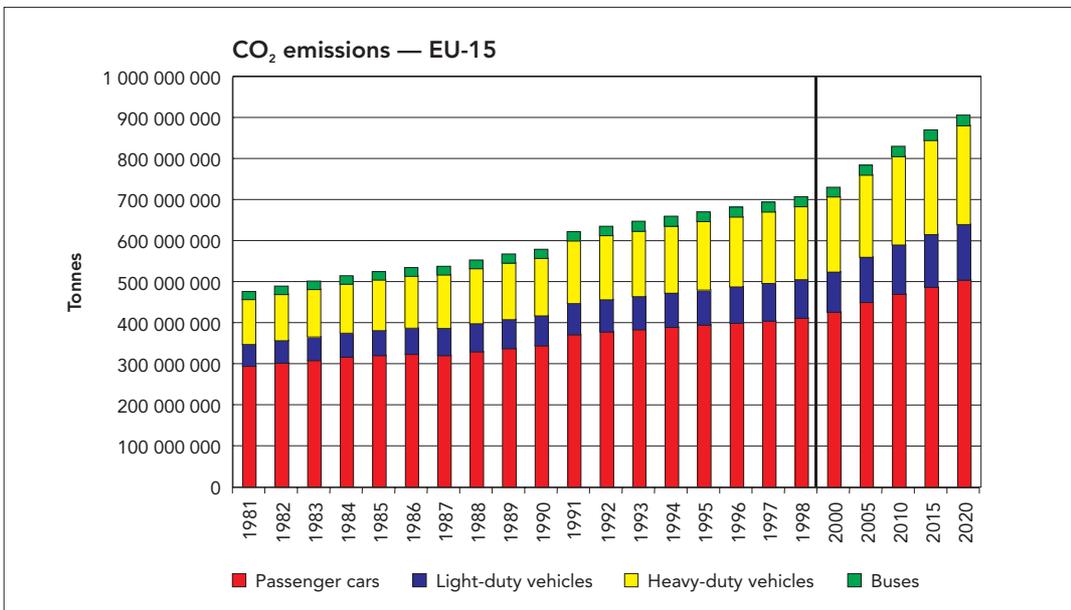


3.6.3. CO₂ emissions

The emissions of CO₂ from all vehicle categories show a general increase from 1981 onwards (Figure 13). The increase is consistent with the increase of the amount of vehicle-kilometres (hence fuel consumption) as presented in Figure 7.

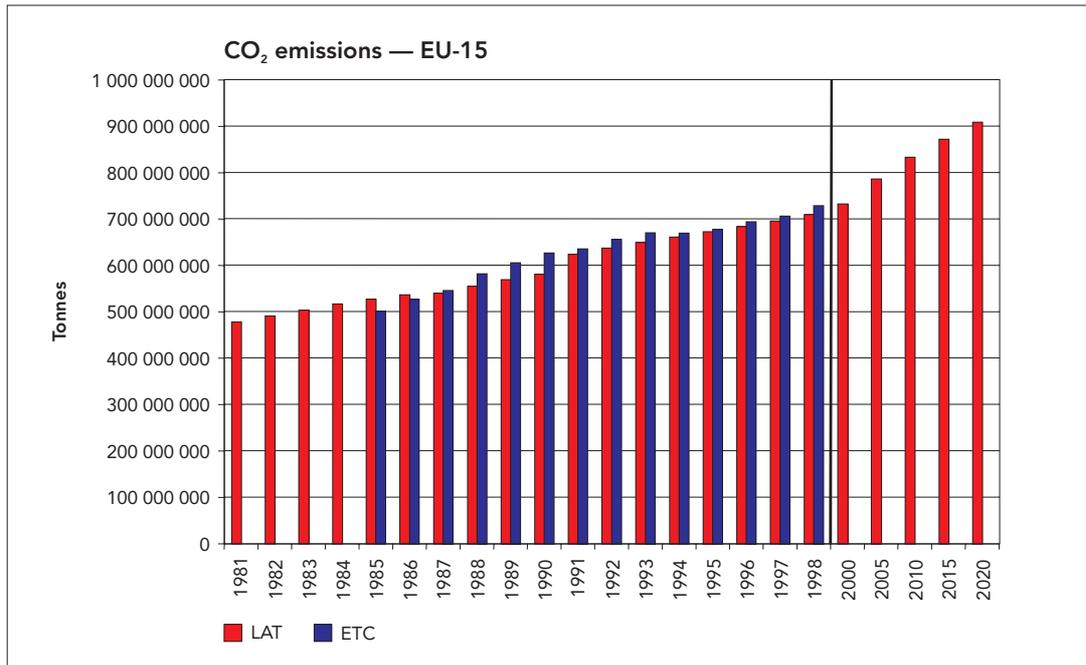
EU-15 — Total CO₂ emissions and contribution of different vehicle categories according to centralised estimates (LAT)

Figure 13



Comparing central and national estimates at EU-15 level shows that it is not possible to make unambiguous statements on which of the methods produces the highest/lowest estimates. The difference between the estimates is generally small. However, differences can be larger at national level (see annex).

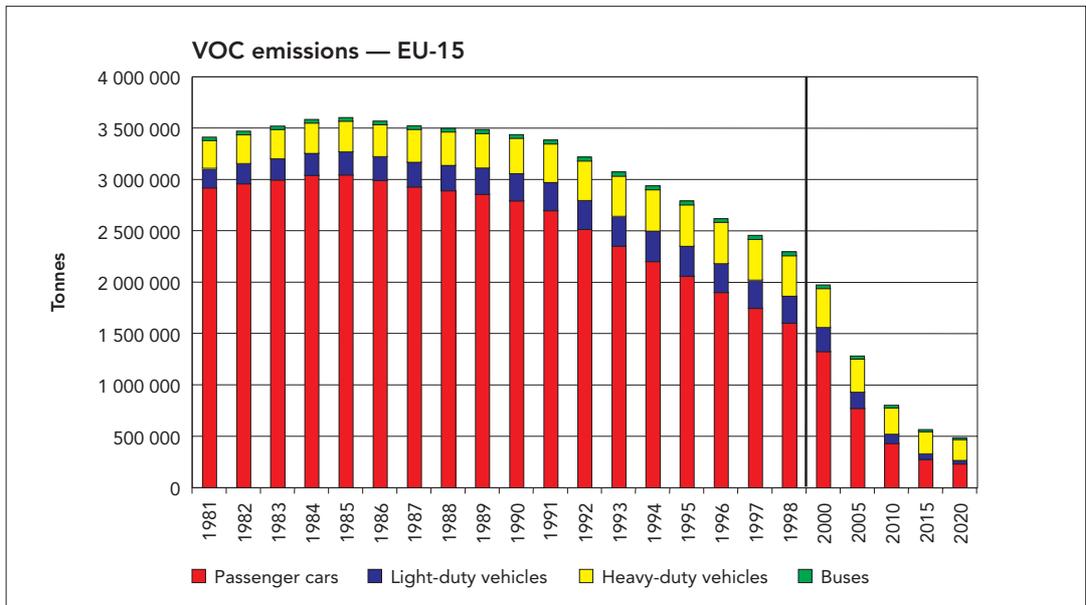
Figure 14 Comparison of centralised CO₂ estimates (LAT) with national data (ETC)



3.6.4. NMVOC exhaust emissions

NMVOC exhaust emissions are similar to those of NO_x (Figure 15) and are dominated by passenger cars, which contribute with approximately 80 % of the total emissions. However, projections indicate a drastic decrease from cars for 2000 onwards, largely as a result of tighter standards.

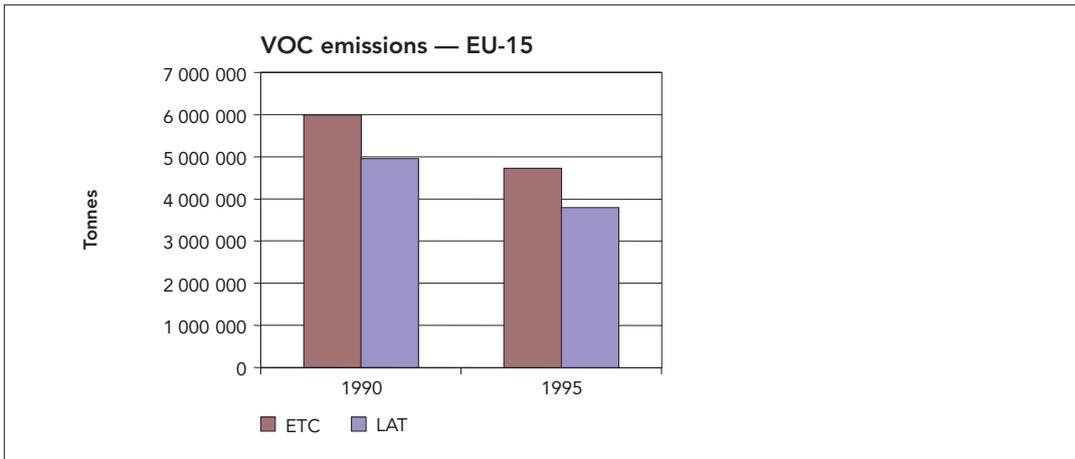
Figure 15 EU-15 — Total VOC emissions and contribution of different vehicle categories according to centralised estimates (LAT)



When comparing central and national estimates for 1990 and 1995 (including evaporation losses), national emission estimates are higher than central estimates. At the national level, however, it is not possible to make unambiguous statements on which of the methods produces the highest/lowest estimates (see annex).

Comparison of centralised total VOC estimates (LAT) with national data (ETC)

Figure 16



4. Comparison of emission projections (RAINS, Tremove, ForeMove/Copert)

This section presents the main findings of a comparison of emission projections produced by different modelling approaches: RAINS (15), (ShAIR) (4), Tremove (Auto-Oil II programme (AOII) (5)) and the ForeMove/Copert (8, 10), based on information available from these models by the end of 2000. The main aim of this comparison is to assess differences in results and to identify the main factors causing these differences.

4.1. Conceptual model structures

RAINS, which is maintained by IIASA, distinguishes between three vehicle categories: two-stroke and four-stroke light-duty vehicles (12) and heavy-duty vehicles (3). Calculations of emissions of NO_x and NMVOC in RAINS are based on fuel consumption by each vehicle category. RAINS distinguishes three types of fuel: light fractions of liquid fuels (petrol and liquefied petroleum gas), medium distillates (diesel fuel) and natural gas. For each vehicle type, the present and future fuel consumption is extracted from the energy scenario for a given country — that is RAINS follows a top-down approach. The energy data used by RAINS for historical years are consistent with international energy statistics (e.g. IEA, 1997). For EU-15 countries, energy projections were generated by the energy model Primes (compare (14)) and include sufficient details about the transport sector. For other countries, usually only more aggregated information is available. Thus the RAINS team, in consultation with national experts, split the road transport emissions into individual categories.

RAINS uses a country-specific ‘uncontrolled’ emission factor for each vehicle/fuel category, reflecting national characteristics in fleet composition and driving modes. These emission factors are derived from national estimates and from the Corinair inventory. Actual emissions are then determined on the basis of the country-specific implementation schedule of emission standards, taking into account the specific turnover rate of national vehicle fleets. Information on these schedules is extracted from the costing studies of the Auto-Oil I programme.

The emissions with the Tremove model are calculated bottom-up with the aid of a transport model and the ForeMove scheme⁽³⁾. The outputs from the transport model activity data are related to passenger and tonne-kilometres for various transport modes and vehicle classes). The latter methodology scheme is explained in Section 3.3. In short, it includes the vehicle dynamics module used to estimate the fleet population for each country and Copert III (in a version close to its final form) for the calculation of detailed, technology-based emission factors and total emissions on the basis of the estimated activity data. Estimations with Copert are performed for a detailed vehicle category split, additionally taking into account activity data on different driving models (i.e. urban, rural, highway, number of cold starts, etc.). Historical data on vehicle stock, population, vehicle use and official population projections are used for the calculation of the future activity trends, whereas age distribution and lifetime functions of vehicle types form the basis for the predictions of the internal turnover of vehicles.

The conceptual differences between the three model approaches are summarised in Table 2.

(3) Although Tremove has fully incorporated the ForeMove approach for forecasting future emissions, there are still differences between the results obtained by these two model schemes due to: (i) eventual differences in the transfer of the methods and (ii) the use of different activity data for the emission estimates.

Conceptual differences between the RAINS (IIASA), Tremove (DRI, Univ. Leuven) and ForeMove/Copert (LAT/AUTH) models

Table 2

Activity	RAINS	Tremove	ForeMove/Copert
Energy/fuel consumption	Input	Product	Product
Transport work (pkm/tkm)	-	Input calculated	-
Vehicle fleet data	-	Input	Input calculated
Emission factors	Input	Calculated	Calculated
Future technology penetration	Input	Calculated	Calculated

4.2. Scope and data for the model calculations characteristics

The calculations with RAINS (IIASA) and ForeMove (LAT/AUTH) were performed for 15 countries, whereas the Tremove model provided results for nine countries in the Auto-Oil II study. The common basis for the calculations were:

- fuel consumption estimates for the years 1990 and 2010 (see annex — Section 10.4) and
- emission estimates for the pollutants NO_x and VOC in five-year intervals from 1990 to 2020 (see annex — Section 10.5, Tables 3 and 4).

An important difference between the ForeMove (LAT) and Tremove (AOII) calculations was that Tremove (AOII) were carried out with data compiled by DRI, in the framework of their project with the European Commission, for the production of the base-case scenario for Auto-Oil II. Comparison of the fleets and fleet activity data of LAT and DRI revealed some major differences and discrepancies. It should also be noted that in contrast to the ‘The ShAIR scenario’ report (4), motorcycle emissions were not taken into account in the Auto-Oil II calculations nor in the ForeMove LAT calculations. Finally, the VOC emissions presented only include exhaust emissions.

4.3. Comparing the model results

The comparison between ShAIR, Auto-Oil II and LAT projections shows that they yield different results (see Tables 3 and 4). The differences between projections on EU level are, as expected, smaller than for individual countries. Thus, the ForeMove projections for EU-15, as presented in Section 3.6, appear reasonably robust given the current state of knowledge and data. For some countries, however, the differences between the three model approaches are significantly larger. For example, NO_x emissions in Finland are expected to drop by 78 and 70 % by 2010 compared with 1990, respectively, according to the results of the ShAIR projection and Auto-Oil II. ForeMove calculates a corresponding decrease of 42 %. Major differences in medium-term projections (to 2010) are also observed for Greece, Italy and Portugal. With the exception of Portugal, ForeMove predicts more moderate emission reductions than with the other two approaches. The picture provided by the long-term trends (to 2020) of NO_x and VOC emissions is more homogeneous in the majority of the countries examined. However, the differences between model results in Finland, Greece and Italy remain significant. Further information on country level may be found in Sections 8.4 and 8.5 of the annex.

There are a number of differences between both Tremove and ForeMove estimates on fuel consumption and the corresponding values provided by RAINS. For some countries, the estimates of Tremove and ForeMove are higher than the figures used in the ShAIR projections, while in other countries it is the other way around.

Table 3

Trends of NO_x and VOC emissions as calculated for the ShAIR study (4), Auto-Oil programme (AOII) and ForeMove/Copert projections (LAT)

Change 1990/2010 (%)						
	NO _x			VOC		
	ShAIR	AOII	LAT	ShAIR	AOII	LAT
Belgium	-68.8		-71.0	-83.0		-78.8
Denmark	-73.6		-73.9	-82.4		-81.0
Germany	-66.8	-72.0	-64.6	-82.4	-79.2	-70.3
Greece	-42.4	-56.5	-24.7	-45.5	-70.3	-36.2
Spain	-50.9	-60.7	-51.0	-65.7	-69.6	-61.9
France	-70.5	-69.9	-72.4	-83.2	-82.0	-77.9
Ireland	-65.4	-64.3	-69.4	-81.8	-72.1	-79.4
Italy	-67.1	-71.4	-59.0	-59.6	-76.5	-70.6
Luxembourg	-83.4		-75.6	-89.9		-78.8
Netherlands	-73.5	-73.4	-71.5	-83.2	-76.5	-76.1
Austria	-66.3		-62.9	-75.4		-71.6
Portugal	-25.9		-42.8	-53.1		-60.2
Finland	-77.9	-69.5	-42.1	-86.6	-72.8	-41.2
Sweden	-75.8		-67.2	-86.6		-74.4
United Kingdom	-78.7	-76.2	-80.5	-90.4	-84.9	-84.0
EU-9/15	-68.9	-70.9	-66.1	-78.4	-79.3	-72.8
Change 1990/2020 (%)						
Belgium	-82.1		-81.6	-88.7		-84.0
Denmark	-87.9		-86.2	-93.3		-88.4
Germany	-83.4	-83.3	-79.3	-90.5	-87.0	-79.2
Greece	-81.2	-69.5	-58.4	-71.4	-77.0	-65.7
Spain	-79.3	-73.4	-71.0	-84.7	-76.4	-77.8
France	-84.9	-77.8	-83.3	-90.8	-86.1	-85.7
Ireland	-82.2	-78.6	-80.4	-91.7	-81.6	-85.2
Italy	-79.5	-82.4	-77.8	-64.6	-84.6	-83.2
Luxembourg	-89.0		-84.9	-93.5		-82.0
Netherlands	-83.7	-79.4	-83.4	-88.6	-81.4	-82.4
Austria	-81.5		-71.7	-83.5		-77.3
Portugal	-70.9		-69.8	-79.2		-75.7
Finland	-88.8	-82.7	-73.7	-94.3	-84.2	-70.3
Sweden	-87.7		-84.3	-92.8		-87.5
United Kingdom	-88.7	-84.2	-88.2	-94.7	-89.2	-88.3
EU-9/15	-84.0	-80.8	-80.5	-86.0	-85.4	-82.7
ShAIR = results from with RAINS assuming the ShAIR scenario (4); AOII = results obtained from Tremove for the Auto-Oil II programme; LAT = results obtained from the centralised approach ForeMove/Copert.						

The differences vary between 7 and 9 % for the nine EU countries in the Auto-Oil II programme for the year 1990, while they are around 12 % for 2010. With regard to NO_x emissions, RAINS estimates are, in general, higher than those of Tremove and ForeMove. The calculated deviations remain well below 20 % for the whole period examined. In the case of VOC emissions, RAINS estimates are constantly higher than those of the other models (in 1990 the difference between RAINS and Tremove is of the order of 26 %). The results of the Auto-Oil II study are in fairly good agreement with ForeMove calculations. The observed deviations between RAINS and Tremove/ForeMove should be attributed to the 2-stroke vehicle emissions accounted for in RAINS calculations. Taking into account 2-stroke vehicle emissions in Tremove/ForeMove would certainly increase the corresponding emission levels.

The aforementioned results suggest differences between bottom-up and top-down projections, especially at national level. These differences need to be clarified. Future comparison with national projections could contribute to the clarification process (see also Section 5.1 where further comparisons are performed for the Netherlands and Germany).

Differences in NO_x and VOC emissions between the ShAIR projections (=100%), the Auto-Oil program (AOII) and ForeMove (LAT)

Table 4

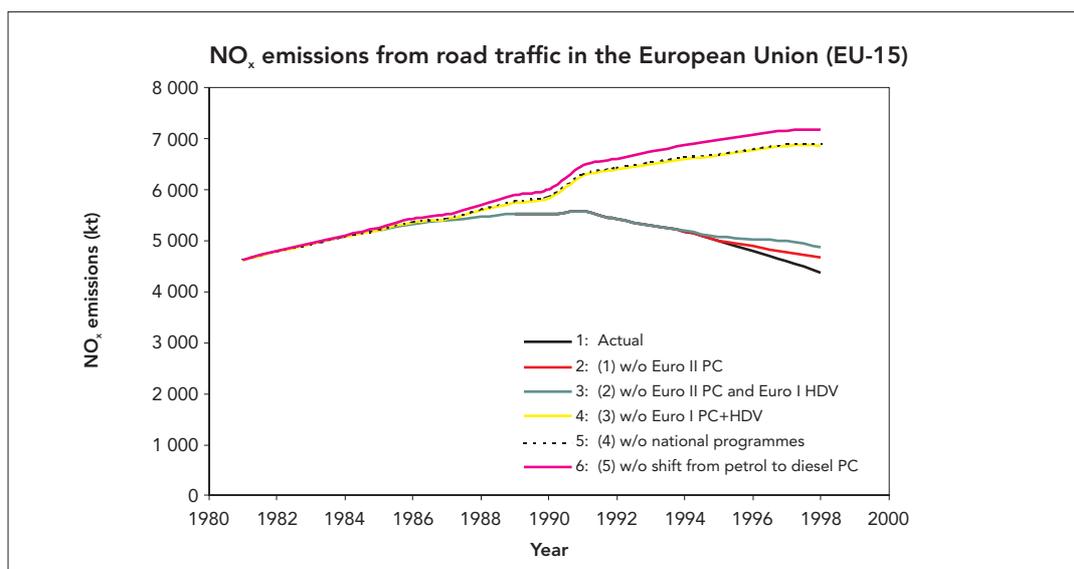
NO _x	1990		1995		2000		2005		2010		2015		2020	
	AOII	LAT												
Austria	49%		21%		33%		27%		63%		104%		128%	
Belgium		2%		1%		8%		-5%		-5%		1%		5%
Denmark		25%		40%		65%		36%		24%		42%		42%
Finland	-17%	-37%	-1%	-20%	6%	3%	14%	40%	15%	64%	26%	69%	28%	47%
France	5%	-16%	-3%	-24%	2%	-21%	6%	-24%	7%	-22%	34%	-11%	54%	-8%
Germany	3%	-26%	-12%	-18%	-5%	-9%	-12%	-20%	-13%	-21%	0%	-11%	4%	-8%
Greece	-7%	-5%	-15%	-3%	-23%	5%	-34%	5%	-30%	24%	7%	92%	51%	111%
Ireland	-14%	11%	-18%	2%	-18%	-5%	-15%	-8%	-11%	-2%	1%	11%	4%	22%
Italy	-18%	-11%	-21%	-16%	-23%	-8%	-25%	3%	-29%	11%	-17%	28%	-30%	-3%
Luxembourg		-1%		40%		50%		25%		46%		33%		37%
Netherlands	-22%	-14%	-13%	1%	-9%	2%	-20%	-11%	-22%	-8%	-15%	-14%	-2%	-13%
Portugal		-25%		-34%		-34%		-39%		-42%		-31%		-23%
Spain	-1%	-5%	-12%	-18%	-18%	-16%	-20%	-11%	-21%	-5%	-1%	13%	27%	33%
Sweden		12%		19%		32%		48%		52%		47%		44%
United Kingdom	-19%	-24%	-23%	-29%	-10%	-24%	-8%	-29%	-9%	-30%	4%	-25%	14%	-20%
EU-9	-8%	-18%	-14%	-20%	-10%	-13%	-13%	-14%	-14%	-11%	3%	1%	11%	0%

VOC	1990		1995		2000		2005		2010		2015		2020	
	AOII	LAT												
Austria		-5%		-1%		3%		5%		10%		20%		31%
Belgium		-24%		-11%		9%		-5%		-5%		-4%		8%
Denmark		11%		32%		62%		29%		20%		74%		93%
Finland	-13%	-35%	18%	-14%	43%	29%	73%	117%	77%	188%	124%	255%	140%	240%
France	-27%	-31%	-19%	-26%	-19%	-16%	-16%	-9%	-22%	-9%	-8%	-3%	10%	7%
Germany	-19%	-36%	2%	5%	12%	20%	-1%	8%	-4%	8%	7%	26%	11%	40%
Greece	-18%	3%	-19%	-2%	-35%	1%	-52%	11%	-56%	20%	-47%	38%	-34%	23%
Ireland	-43%	3%	-45%	-16%	-38%	-11%	-24%	1%	-13%	17%	14%	54%	26%	84%
Italy	-39%	-7%	-38%	-27%	-42%	-22%	-50%	-24%	-64%	-33%	-64%	-35%	-73%	-56%
Luxembourg		-35%		3%		12%		-3%		38%		49%		81%
Netherlands	-34%	-19%	-9%	-1%	6%	19%	-8%	10%	-7%	16%	-2%	19%	8%	26%
Portugal		-6%		-28%		-27%		-28%		-20%		0%		10%
Spain	-6%	7%	-6%	1%	-9%	6%	-10%	18%	-17%	19%	19%	47%	44%	55%
Sweden		14%		42%		64%		93%		118%		105%		98%
United Kingdom	-29%	-30%	-28%	-31%	-12%	-14%	8%	5%	13%	17%	36%	39%	45%	54%
EU-9	-26%	-23%	-20%	-18%	-18%	-7%	-21%	-3%	-29%	-3%	-19%	5%	-23%	-5%

5. Effectiveness of measures to reduce NO_x emissions from road transport

The ForeMove/Copert approach (see Section 3.3) was used to assess the effectiveness of policy measures to abate NO_x emission. The assessment was performed for the period 1981–98 (Figure 17).

Figure 17

Effectiveness of measures to reduce NO_x emissions from road transport in EU-15

Nitrogen oxide emissions from road transport in EU-15 Member States increased by about 20 % from 1980 to 1990 and were then reduced, so that by 1998 they essentially returned to the 1980 levels.

The fact that the emissions did not continue to increase in line with traffic growth was mainly due to the introduction of three-way catalyst cars in the late 1980s and early 1990s. Although many Member States had encouraged the penetration of catalyst cars already before 1990, Directive 91/441/EEC made it happen in all Member States. Emission standards for heavy-duty vehicles, as demanded by Directive 91/542/EEA stage I, also contributed to the emission reduction although to a smaller extent. Without these measures, nitrogen oxide emissions by traffic in the EU would have been 50 % higher in 1998.

After 1995, the effects became apparent of the introduction of stricter emission standards for both heavy-duty vehicles (91/542/EEA stage II) and passenger cars (94/12/EC). It is expected that these will lead to further reductions in the near future.

Additional measures at national level, implemented in the late 1980s, such as the early introduction of oxidation catalysts for petrol cars, did not have any significant effect, because stimulating three-way catalysts was a much more drastic measure.

The gradual increase in sales of diesel passenger cars in some European countries contributed further to a reduction in nitrogen oxide emissions, which was significant in Belgium, Germany, France, the Netherlands and Austria. EU-wide, dieselisation caused a drop in emissions of 2–4 % in the 1990s.

As noted in Section 3.6.1, the impact of the 1999 directives will only be measurable after the year 2000. However, it is expected that already in 2000 NO_x emissions will be reduced by 6–10 % compared with their 1998 levels.

5.1. Assessing the robustness by comparing central and national estimates

This section presents an introductory and more in depth, analysis of the robustness of the previous assessment by comparing central and national estimates for both the Netherlands and Germany. Thus, it is a more thorough, and more focused, comparison between the central and national estimates presented in Section 3.6.

5.1.1. Assessment for the Netherlands

The following data sets of NO_x emissions for the Netherlands were used and compared for the years 1981–98.

Central estimates:

- LAT NO_x emissions calculations using Copert emissions functions and activity data compiled primarily in the framework of MEET (called ‘LAT (MEET data)’);
- LAT NO_x emissions calculations using Copert emissions functions and activity data provided by RIM (called ‘LAT (new activity data)’).

National estimates:

- NO_x emissions estimates provided by the Dutch National Institute of Public Health and the Environment (RIVM) ⁽⁴⁾;
- NO_x emissions estimates provided to UNECE/UNFCCC (denoted ‘ETC’) (see Section 3.6).

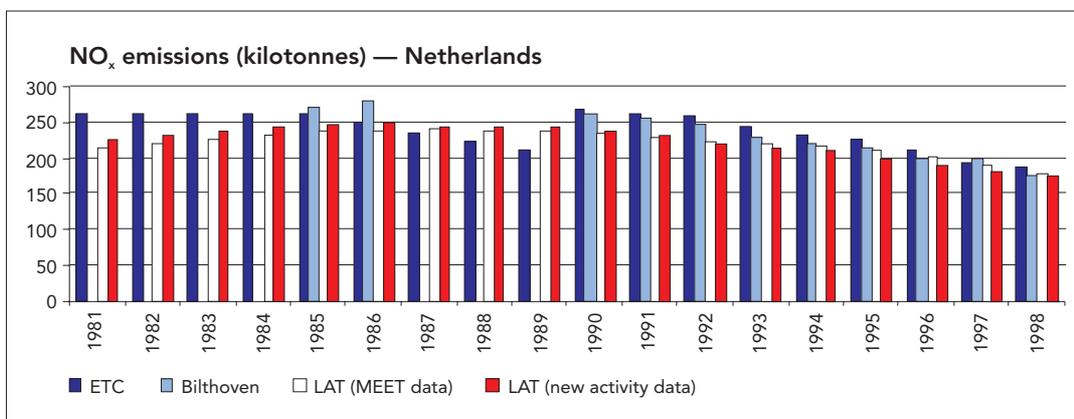
There are relatively large differences (up to 20 %) for the period 1981–90 between national central estimates (Figure 18). Generally, LAT estimates are lower than national estimates. An important part of the difference comes from HDV emissions. The observed differences seem to be suppressed for the more recent years, in particular after 1995.

The differences between ‘LAT (MEET data)’ and ‘LAT (new activity data)’ are minor. This indicates that the deviations have to be attributed to differences in emission factors. However, there are differences between ETC and RIVM emission estimates, despite the fact that the emission estimates reported by ETC should in principle be exactly the same as the national data. We presume that these differences are due to the fact that RIVM data were recently released (hence they are not yet taken on board by ETC). Moreover, in the ETC estimates it is difficult to understand why there is a reduction between 1986 and 1989, followed by a substantial increase in 1990.

The overall trends are quite similar for all emission sets, despite the fact LAT calculations do not include motorcycle emissions (they have a negligible share in NO_x emissions).

Comparison between ForeMove/Copert and national estimates for the Netherlands

Figure 18

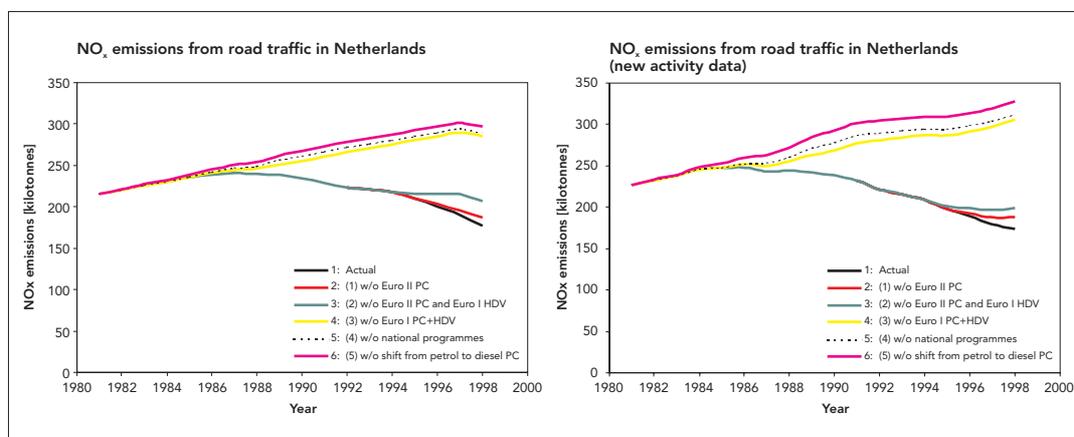


(4) Data used in ‘Environmental balance 2000’, provided by RIVM. The data presented in Figure 19 do not contain non-road transport and, in principle, account only for ‘national’ freight transport.

There are minor differences in the emission trends between the two LAT runs (Figure 19). The results obtained with the new activity data indicate an increase in the effect of the ‘national incentive programmes’ and the ‘shift from petrol to diesel’ from 1996 onwards. However, the effect of these measures remains much less pronounced than the one derived from national approaches. This deviation should be attributed to the different emission factors used in the calculations. It is of importance to stress that LAT is sceptical about the statement in the ‘Environmental signals 2000’ report ⁽⁵⁾ that ‘diesel cars tended until recently to have lower emissions per kilometre than petrol cars’. This is true for non-catalyst cars, but all experimental data indicate that diesel cars emit amounts of NO_x higher than (or equal) catalyst-equipped cars. However, the large difference (or benefit from dieselisation) is found after 1993, a period of high penetration of catalyst-equipped cars in the Netherlands. In conclusion, the policy message as regards dieselisation remains uncertain.

Figure 19

Effectiveness of measures to reduce NO_x emissions from road transport in the Netherlands — Comparison between the results obtained with the MEET data (left) and the corresponding estimates produced with the new activity data (right)



5.1.2. Assessment for Germany

The following data-sets for Germany were used and compared for the period 1981–98:

Central estimates:

- LAT NO_x emissions calculations using Copert emissions functions and activity data compiled primarily in the framework of MEET (called ‘LAT (MEET data)’).
- LAT NO_x emissions calculations using Copert emissions functions and activity data provided by Eurostat (called ‘LAT (new activity data)’)

National estimates:

- NO_x emissions estimates provided to UNECE/UNFCCC — denoted ETC (see Section 3.6).

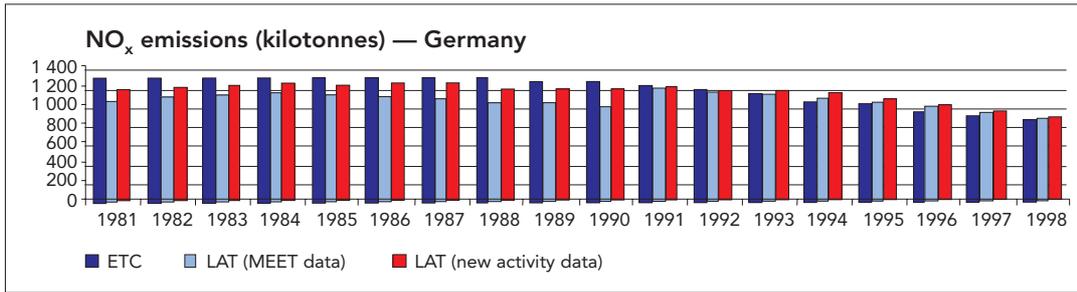
The results of the comparison are similar to the ones for the Netherlands (Figure 20). However, there are large differences between ETC and the LAT (MEET) emission estimates for the period 1981–90. This is due to the fact that the LAT (MEET data) calculations do not take into account the former German Democratic Republic until the year 1990. From 1991 onwards, when the former German Democratic Republic vehicle fleet data are included in the LAT (MEET) calculations, the differences between all estimates are minor.

When examining the effectiveness of measures, the use of the new activity data does not result in significant differences when compared with the MEET data estimates (Figure 21). While, though, the latter indicate that dieselisation contributed to a further reduction of NO_x emissions in Germany, the use of new activity data does not lead to similar conclusions.

(5) <http://themes.eea.eu.int/toc.php/improvement/policy?toc=39368>

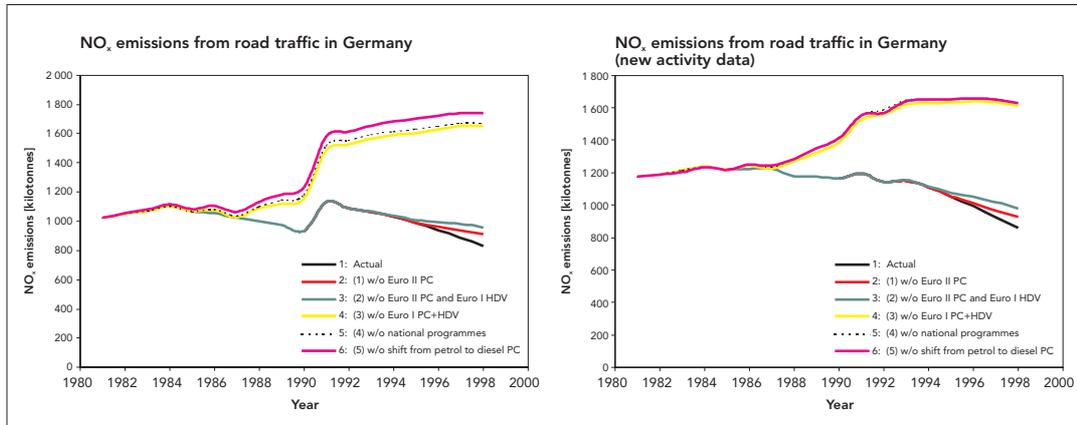
Comparison between ForeMove/Copert and national estimates for Germany

Figure 20



Effectiveness of measures to reduce NO_x emissions from road transport in Germany — LAT (MEET data) (left) and LAT (new activity data) (right)

Figure 21



6. Conclusions and recommendations

Conclusions

- A substantial decrease in emissions of air pollutants has taken place and is also projected up to 2010–20 while CO₂ emissions are projected to increase, largely due to an increase in the projected total number of vehicle-kilometres — in particular by passenger cars.
- The reduction in NO_x emissions during 1980–98 is primarily due to the introduction of three-way catalysts in new petrol-engine cars. A limited comparison, using national information and EU-wide models, of the effectiveness of abatement measures for NO_x emissions did not show significantly different results.
- The comparison between the ForeMove/Copert central estimates (LAT) and national data (ETC) for the period 1981–98 showed that the general trend of air emissions on EU-15 level were similar for both assessment methods. Comparisons of estimates at the national level often displayed differences in the trend and showed that the magnitude of the different estimates could differ significantly for some pollutants and countries. Thus, it was not possible to make unambiguous statements regarding the relative performance of the different approaches.
- There are deviations between projections from different modelling approaches, and they are particularly significant for data disaggregated at national level. The difference in results between top-down and bottom-up approaches needs further clarification. Further comparison with national projections, in addition to those initially performed for the Netherlands and Germany, could contribute to the clarification process.
- Central approaches are useful to assess the effectiveness of policy measures towards reducing NO_x emissions from road transport. The effects of some measures taken to abate emissions from road transport are clear, irrespective of the emission inventory model used. An unambiguous example is the effect of introduction of three-way catalysts to petrol cars. However, other effects, such as those produced by fleet dieselisation, are difficult to estimate since they are in the range of uncertainty related with the emission factors themselves.

Recommendations

In order to improve the quality of central as well as national estimates it is proposed:

- to harmonise the definitions for model parameters, to achieve more uniform data-sets;
- to develop and/or apply new methods to fill data gaps;
- to improve the calibration of the calculation model using robust data from selected years;
- to increase model understanding by investigating the main causes for deviations using sensitivity analysis;
- to perform more in-depth comparisons with other central and national models;
- to improve the statistical analysis of differences between national and central estimates.

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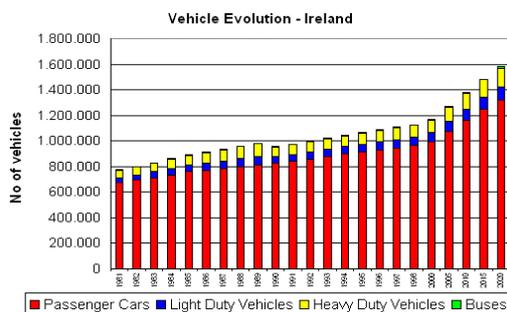
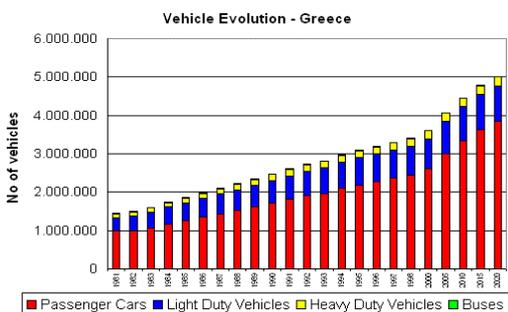
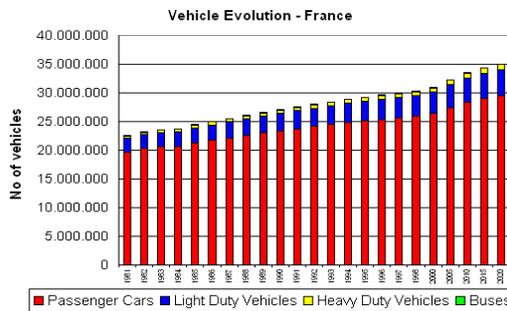
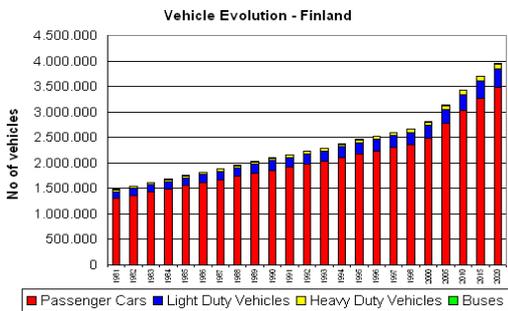
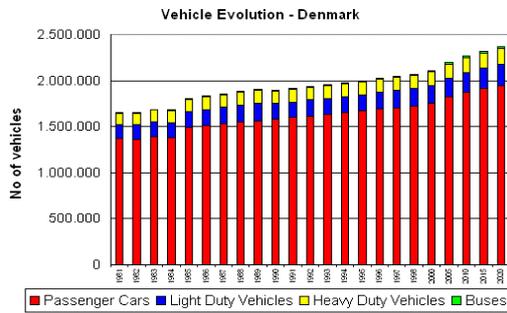
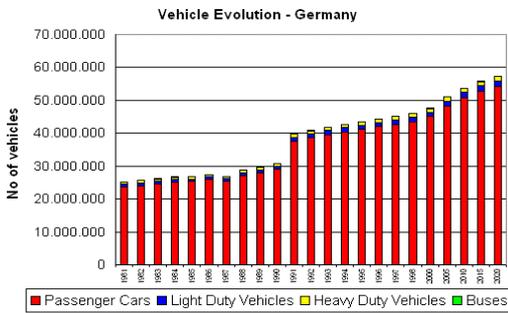
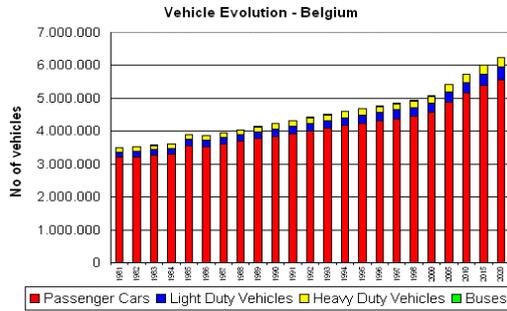
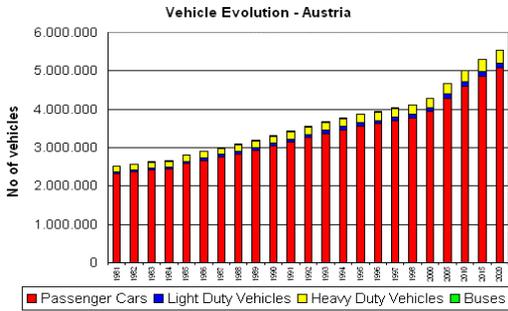
8. Annex: Emission estimates calculated with Copert, RAINS and Tremove

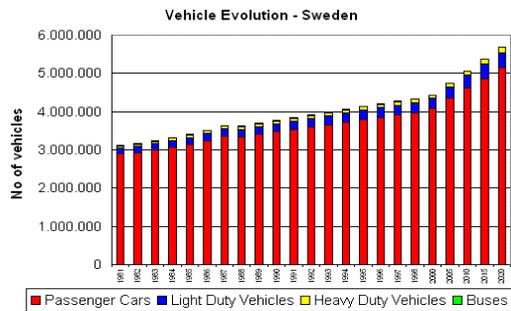
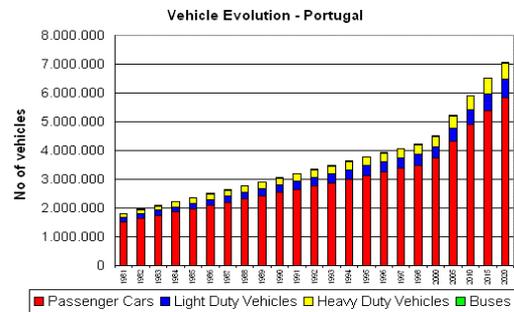
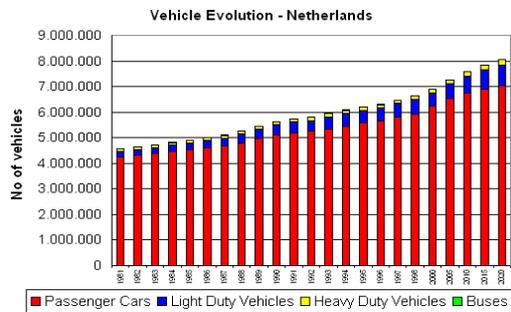
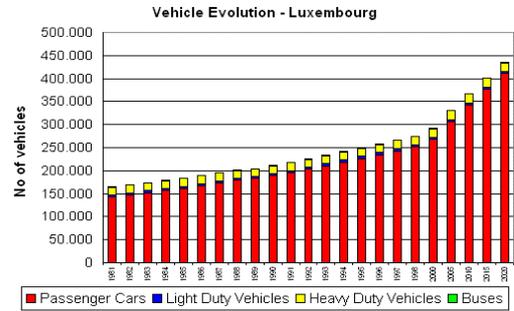
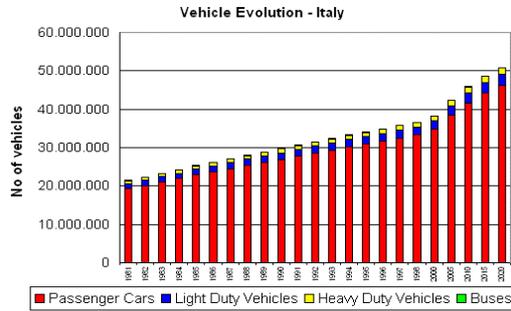
The following sections for vehicle fleet characteristics (8.1) and emissions (8.2) present results of Copert model runs that were performed during year 2000. Data presented from models in the other sections in this annex are those available to EEA by the end of year 2000.

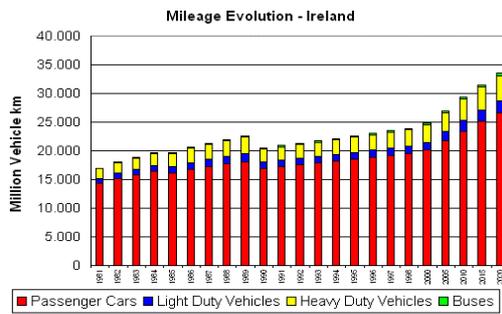
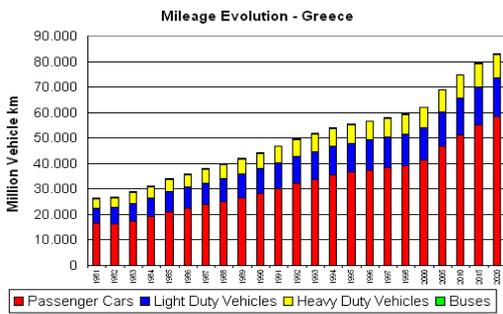
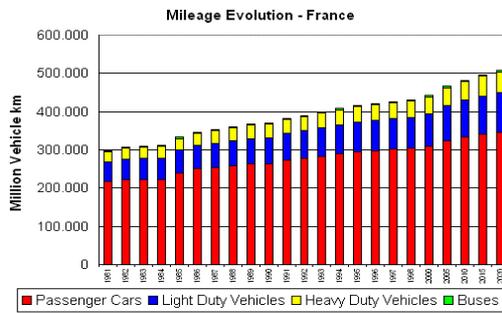
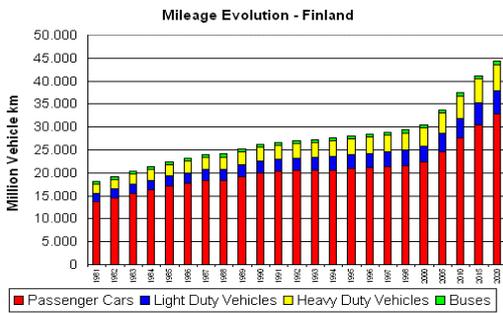
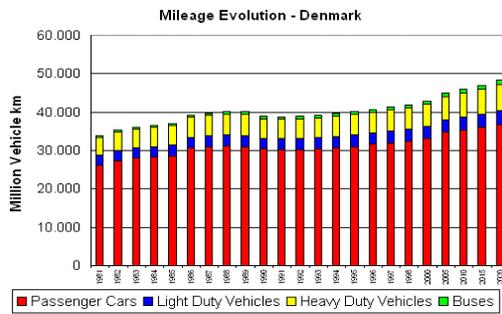
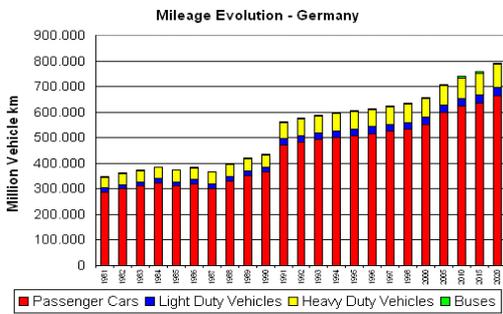
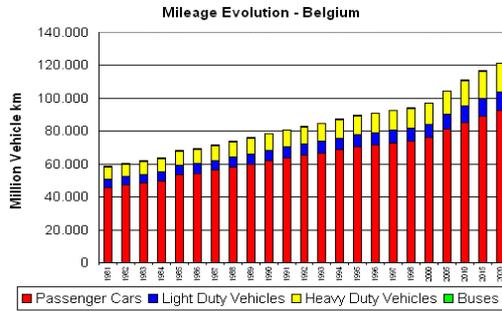
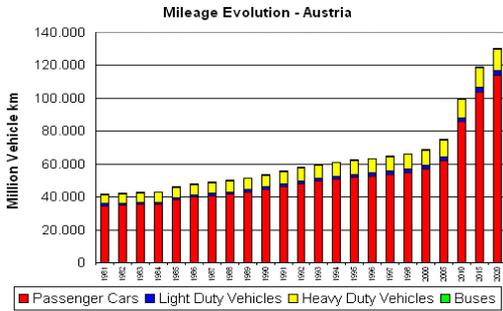
National data in Section 8.3 (denoted 'ETC') is data reported by countries to the EEA by September 2000 (UNFCCC format and CLRTAP/Corinair format separately).

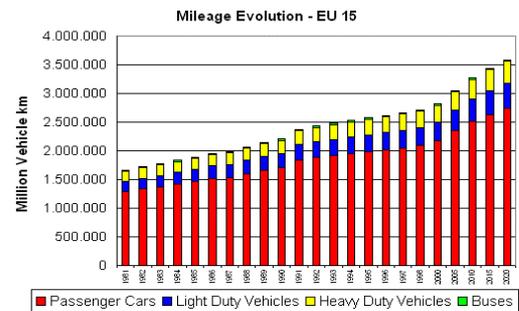
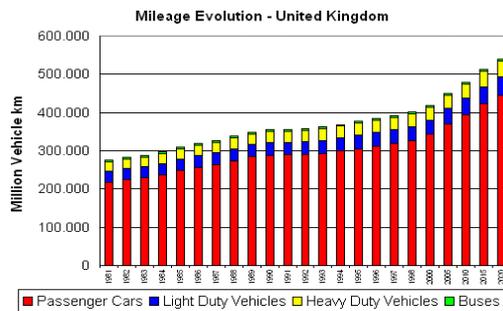
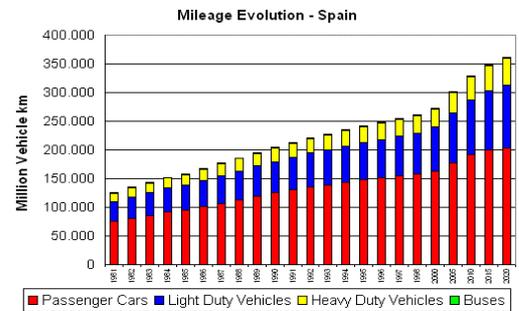
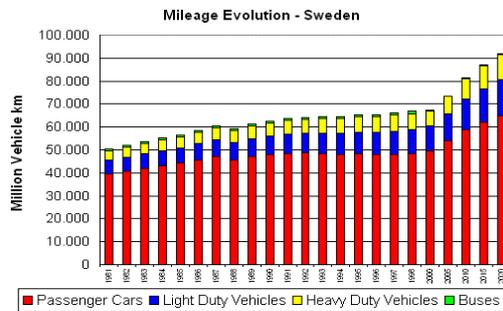
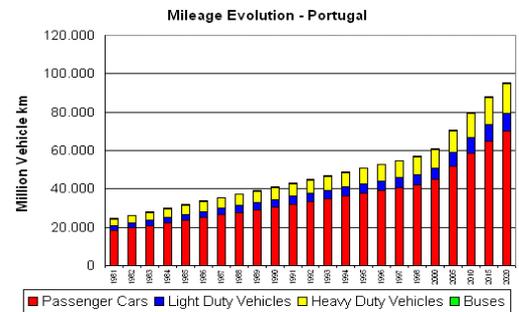
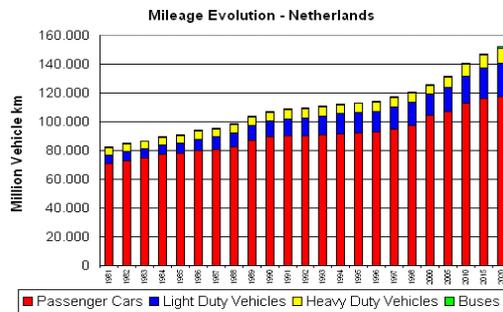
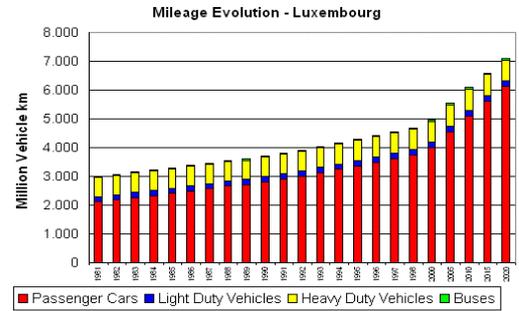
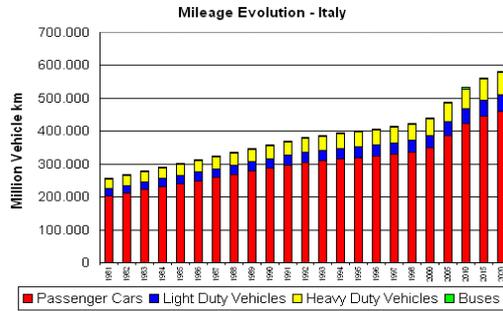
8.1. Fleet characteristics (estimated using Copert)

8.1.1. Vehicle evolution

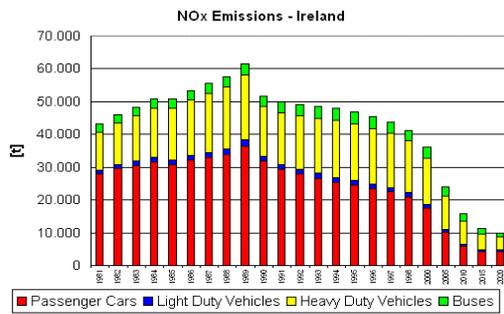
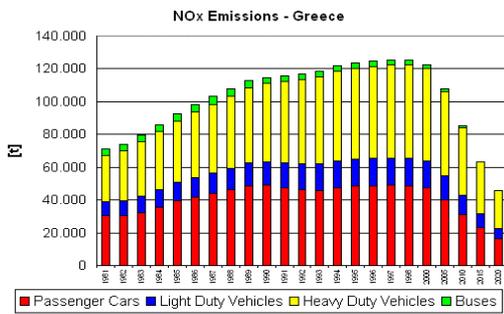
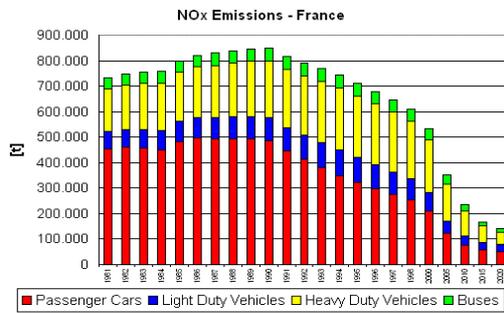
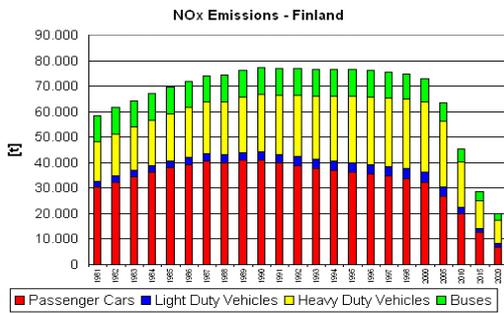
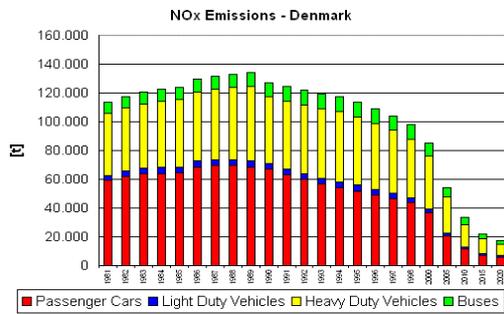
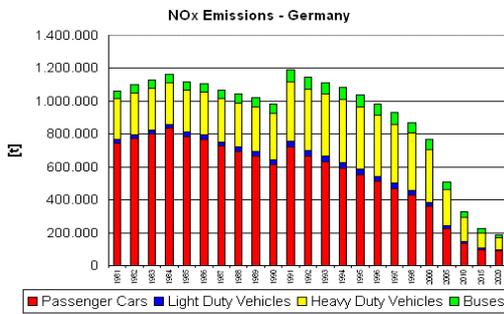
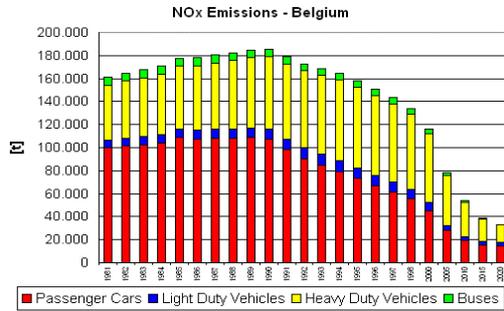
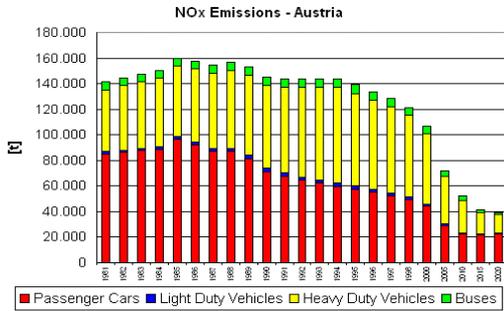


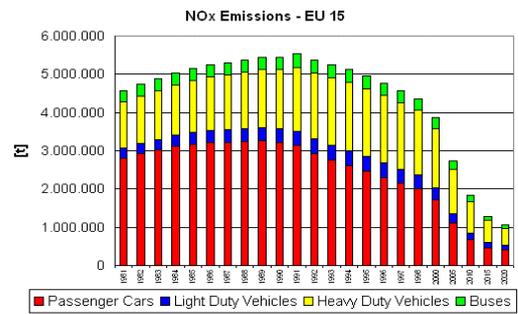
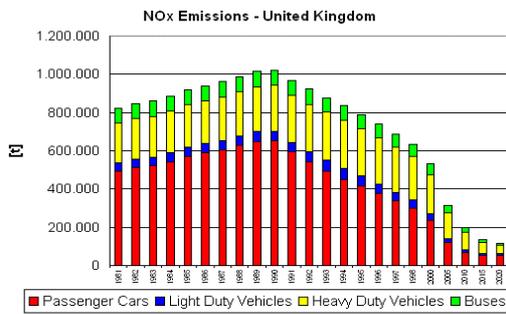
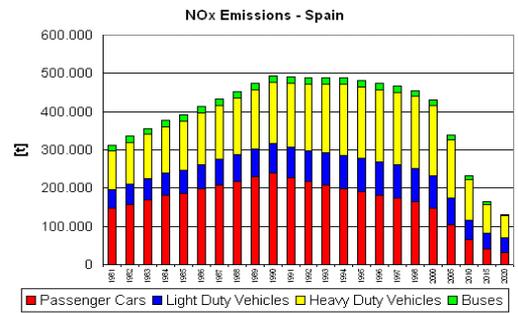
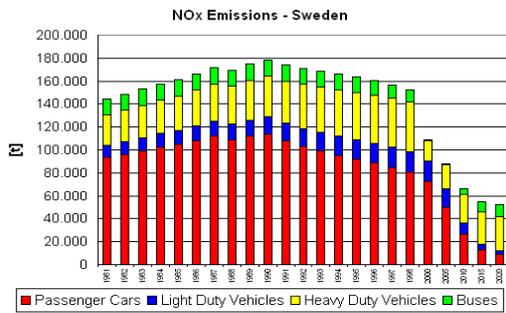
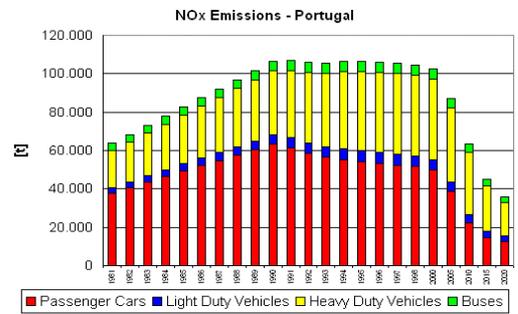
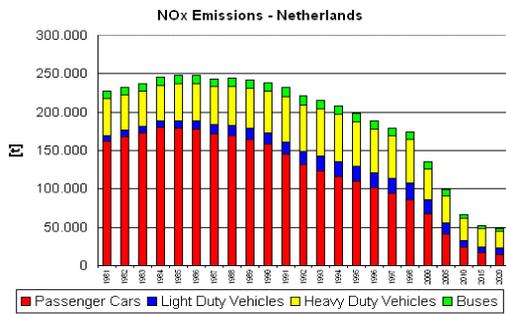
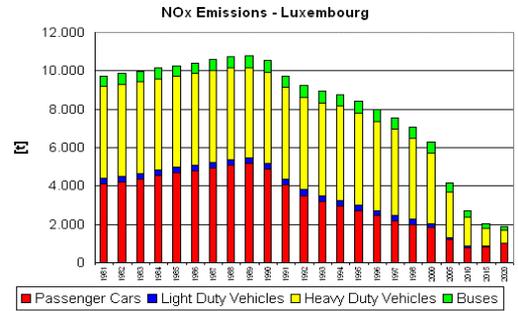
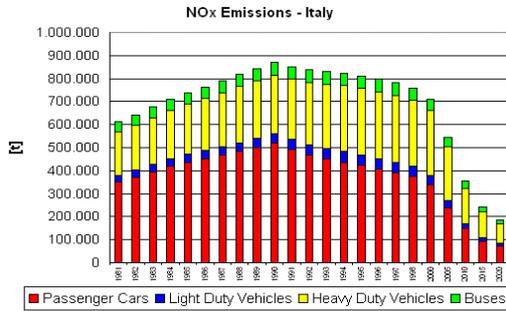


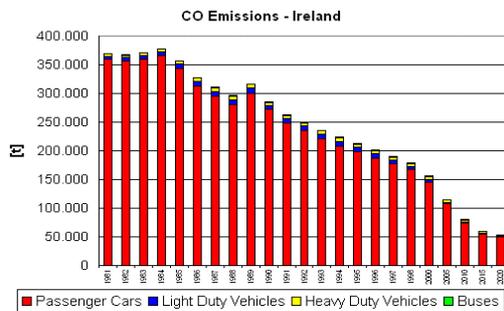
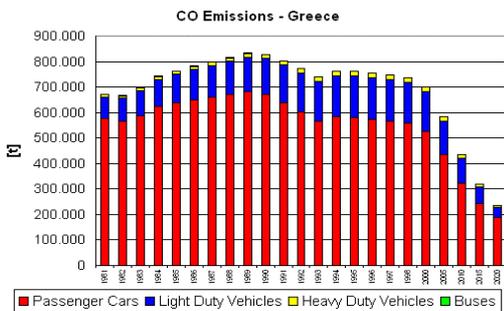
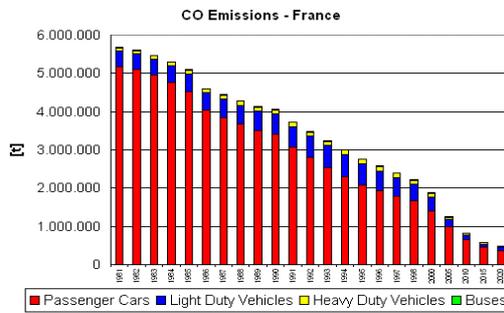
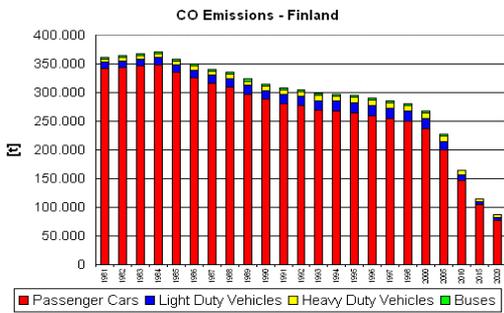
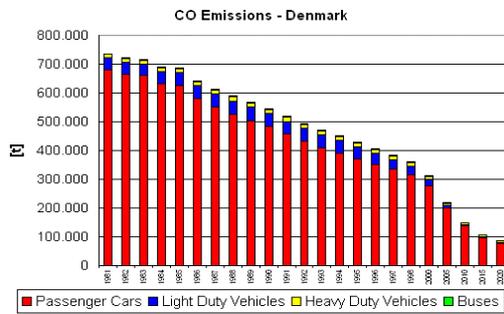
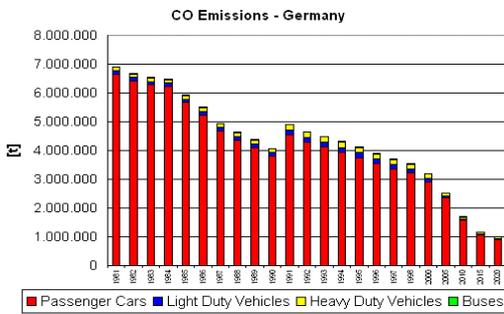
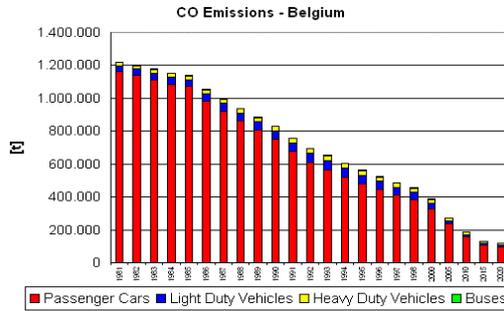
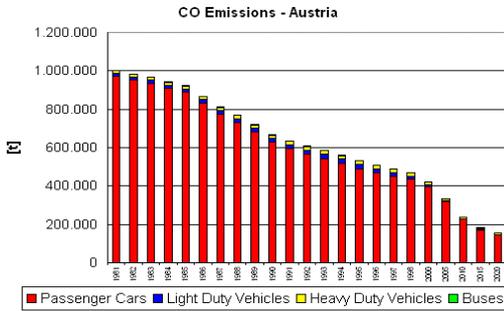


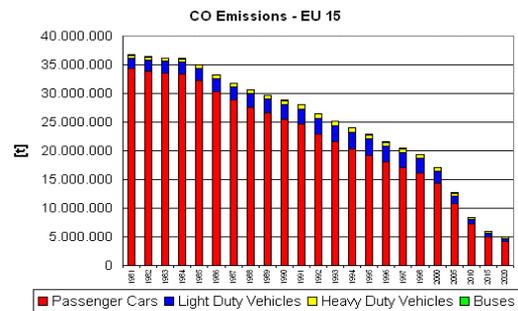
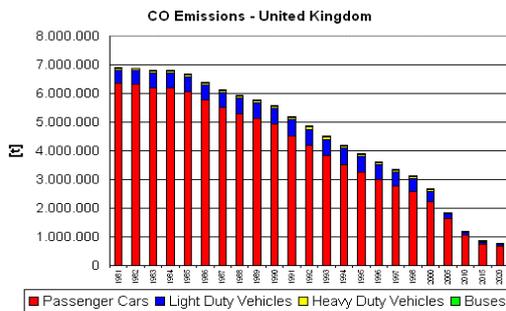
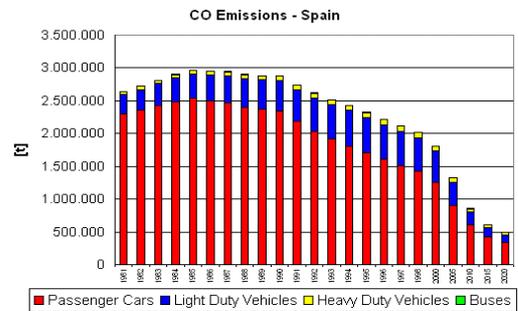
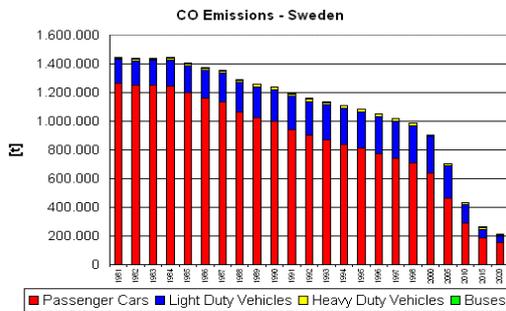
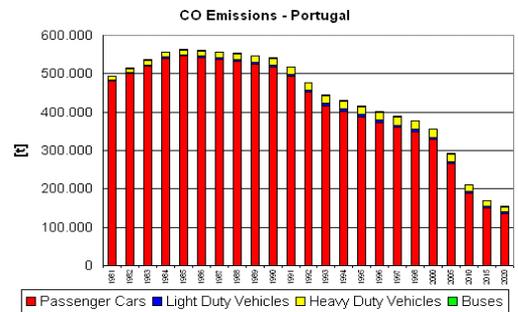
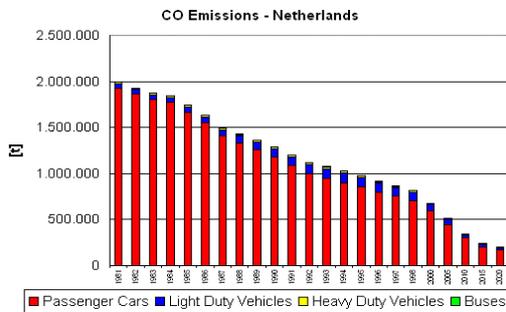
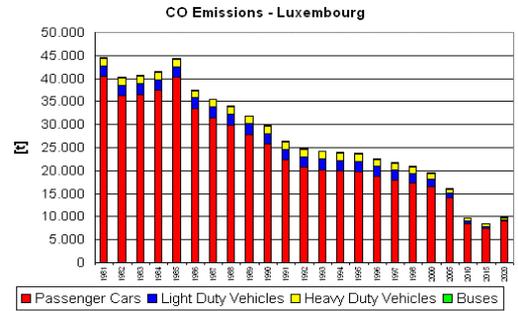
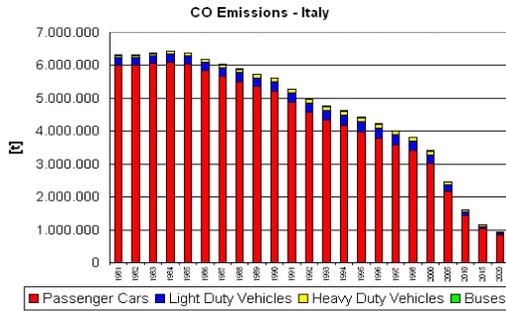


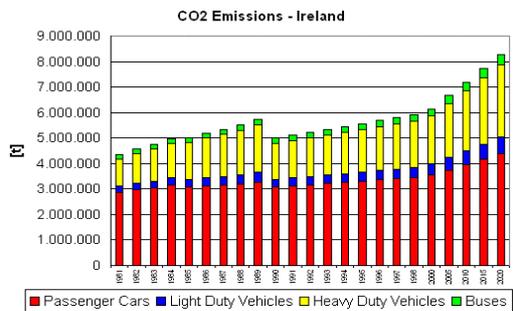
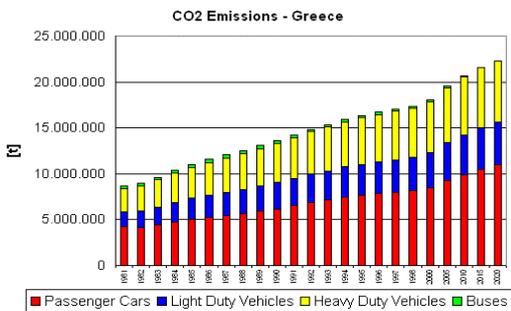
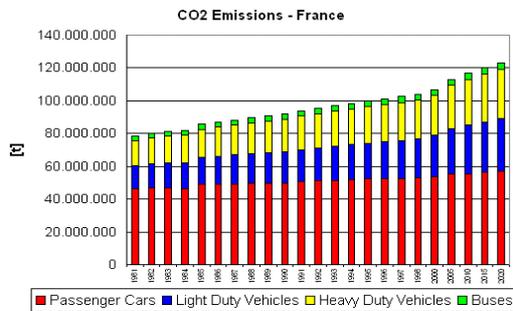
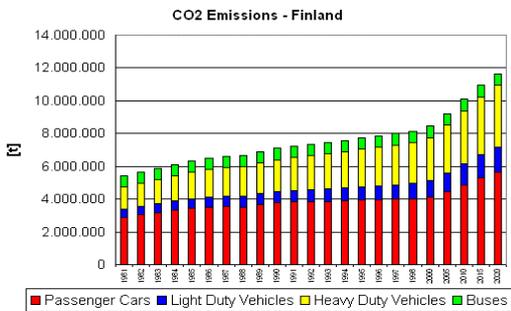
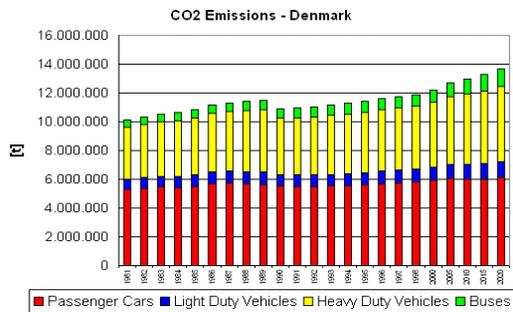
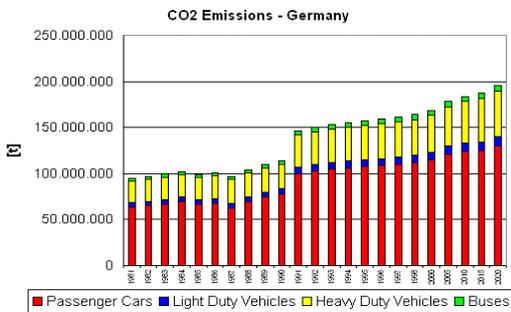
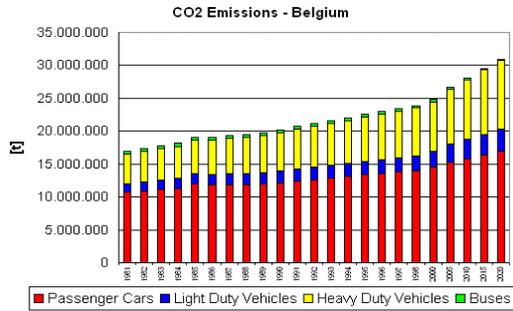
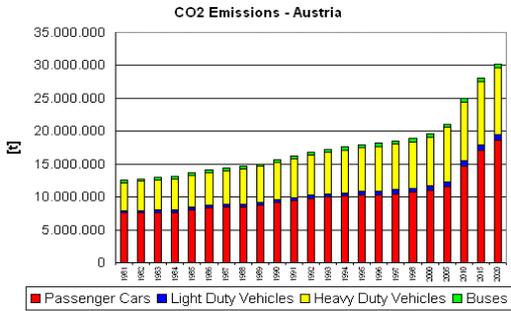
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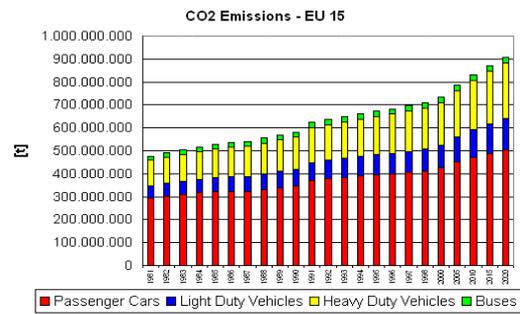
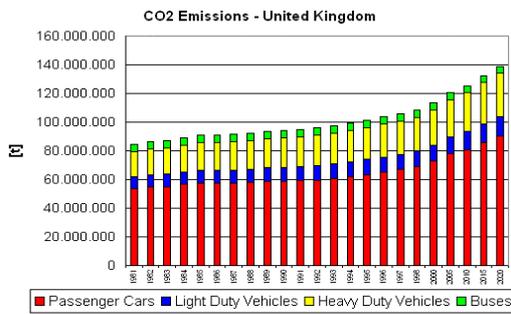
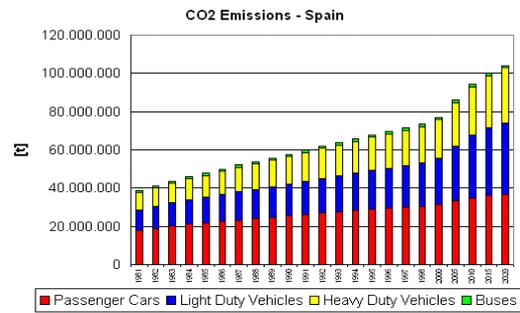
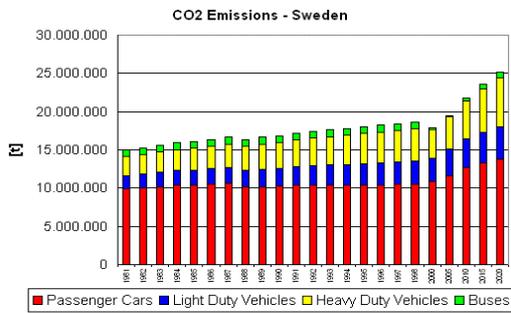
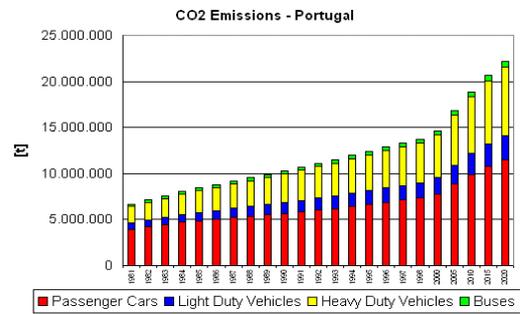
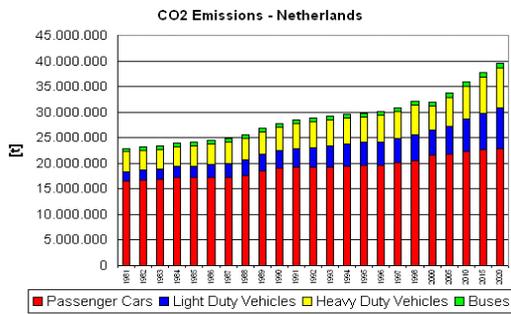
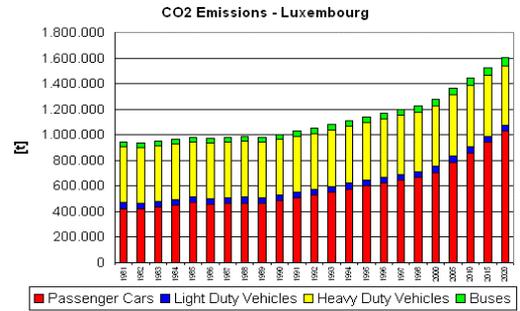
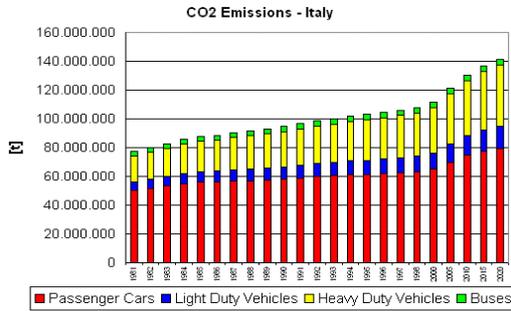


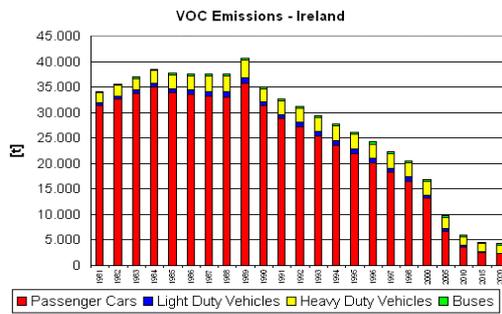
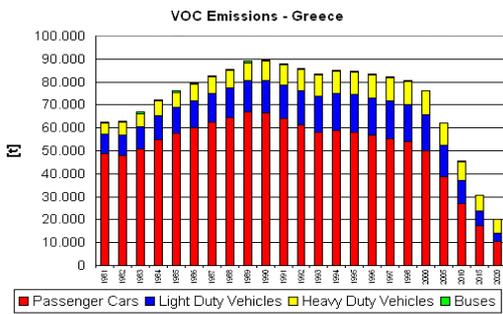
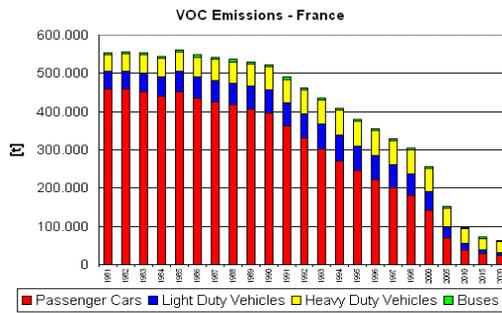
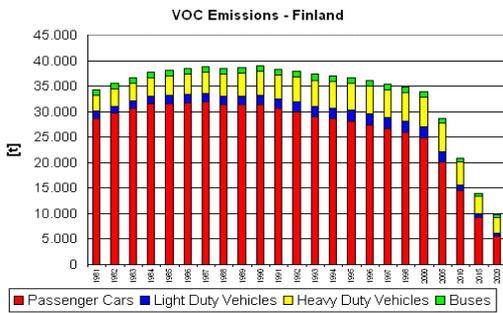
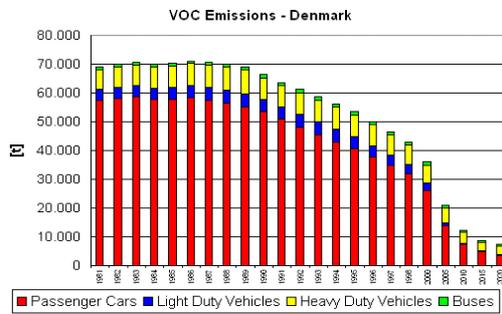
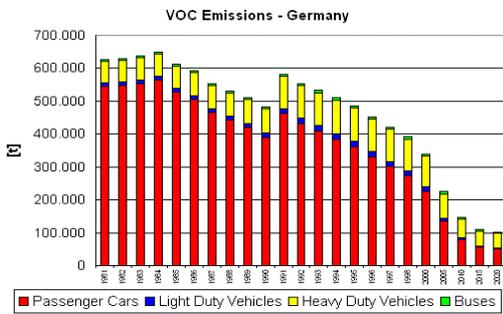
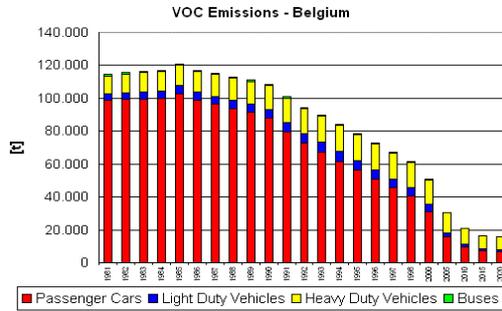
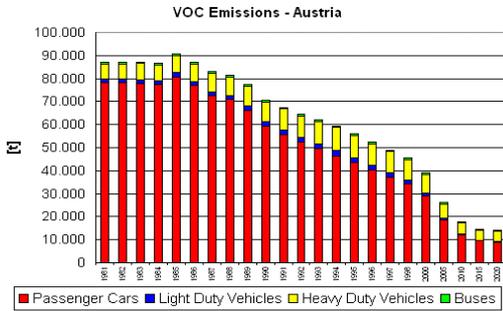


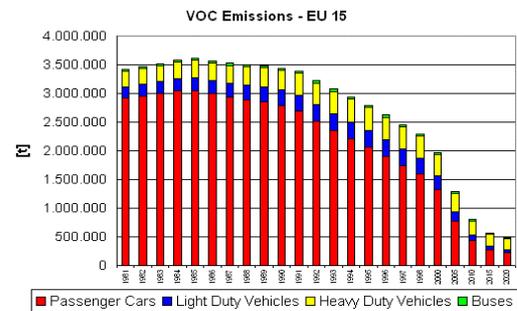
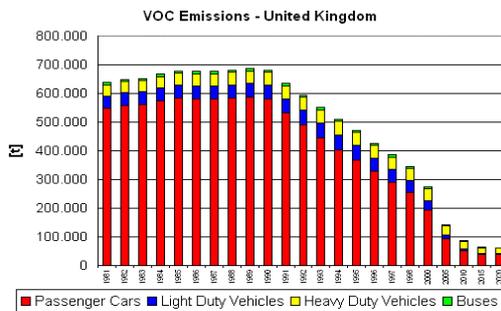
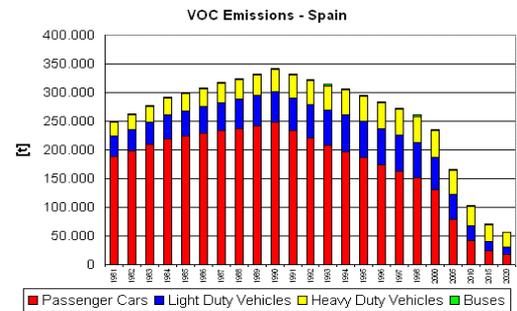
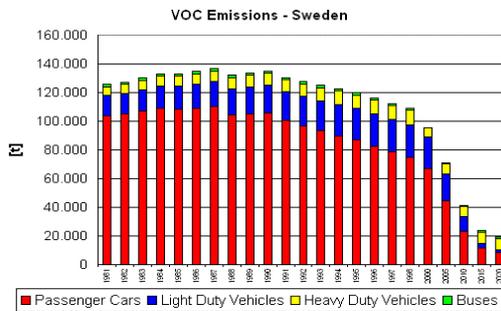
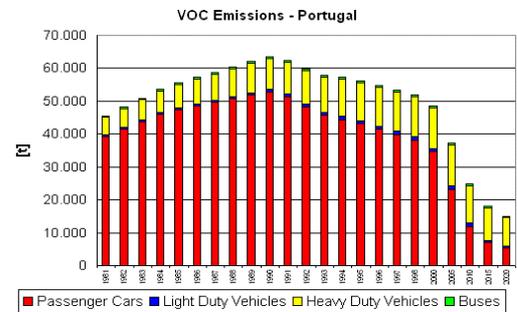
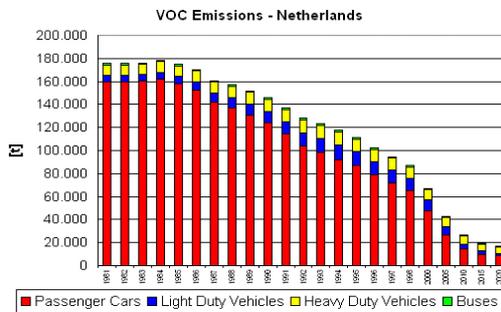
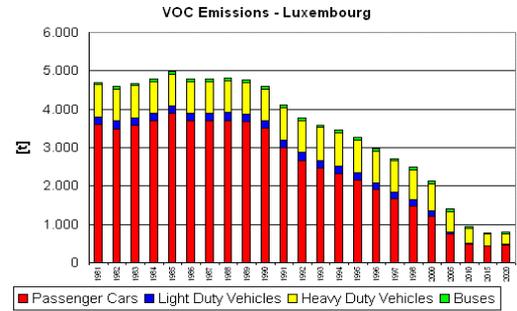
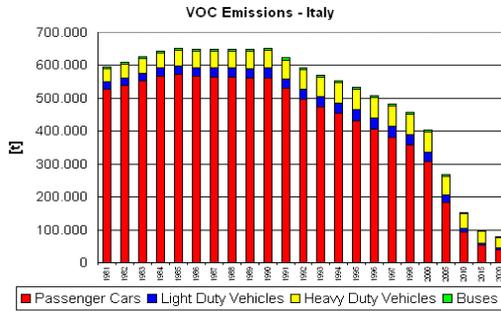




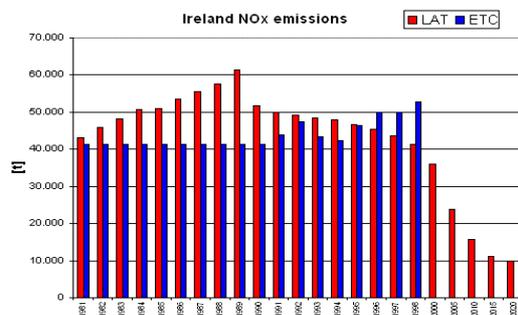
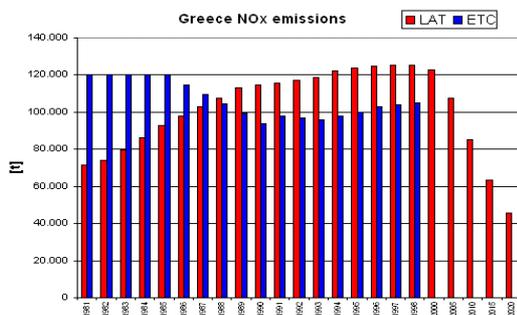
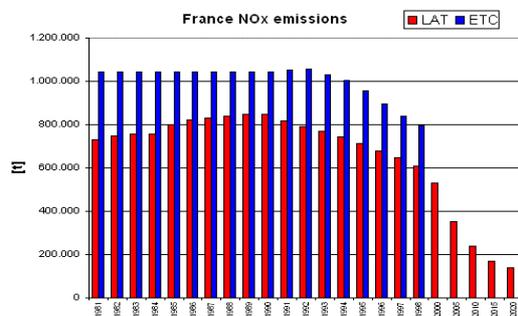
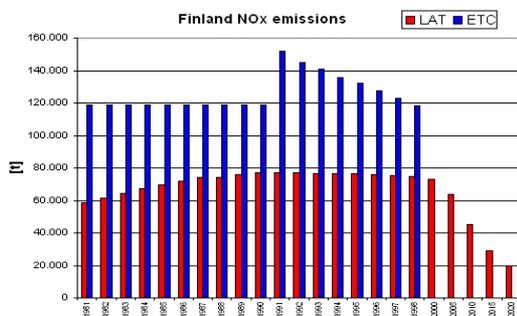
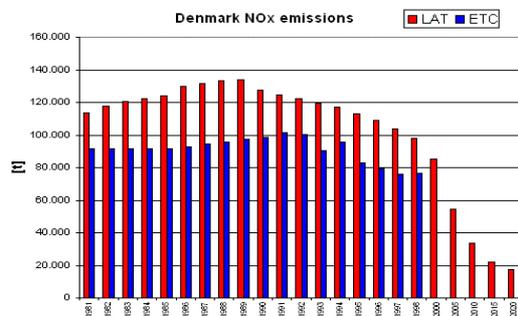
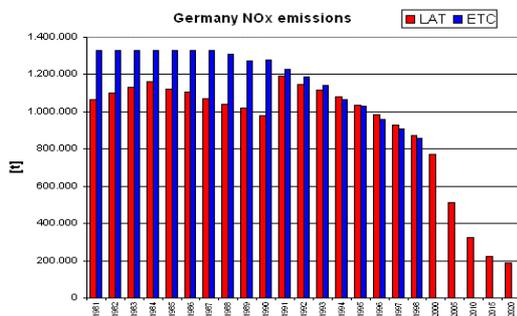
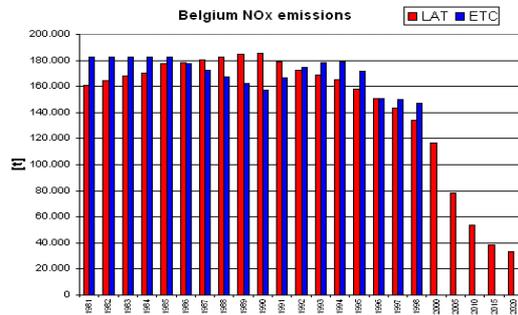
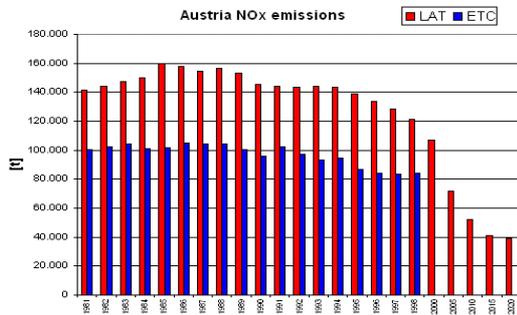


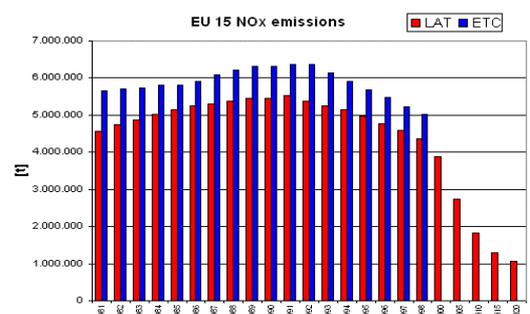
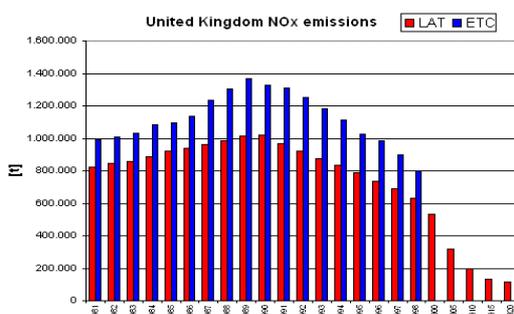
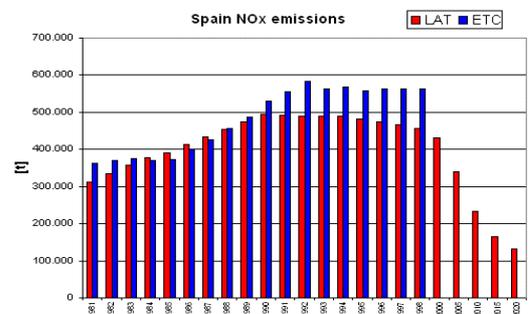
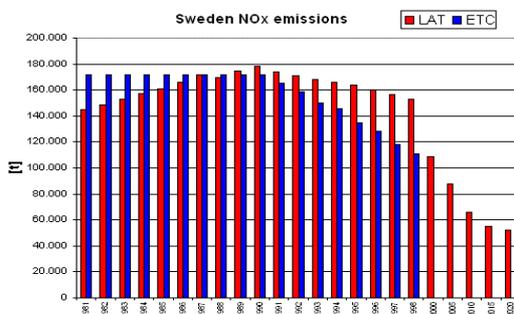
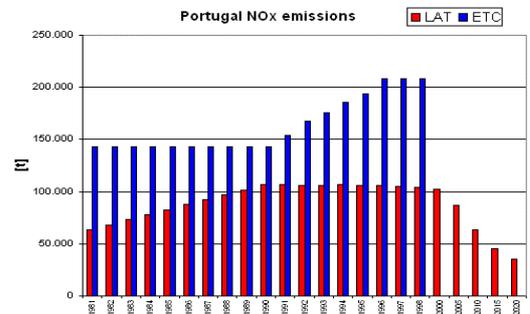
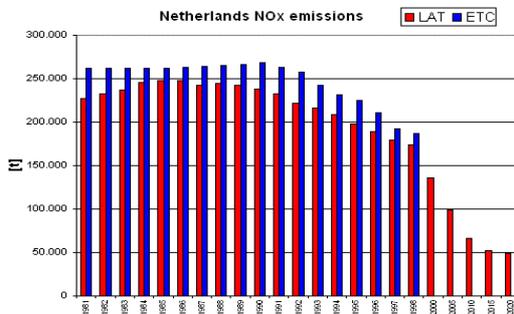
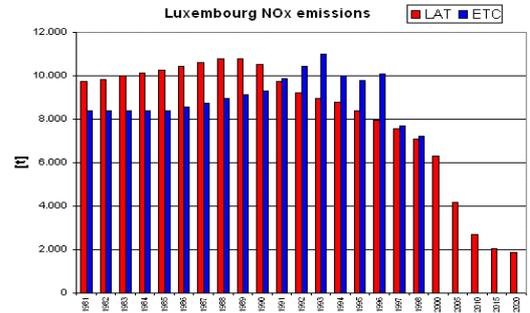
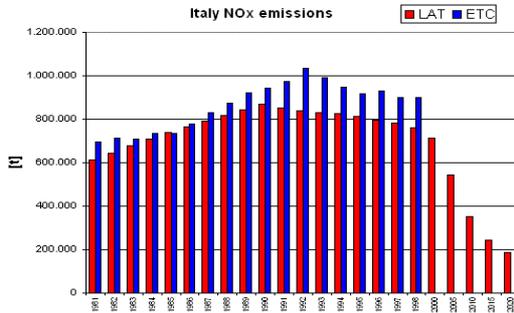


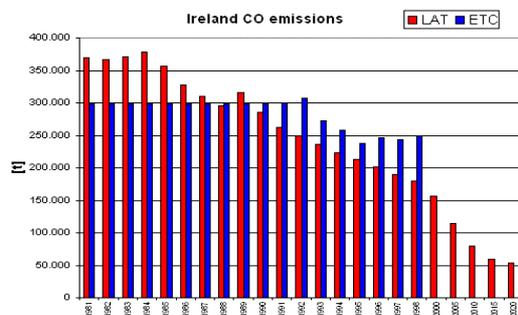
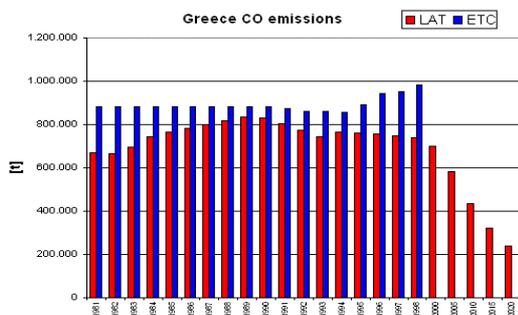
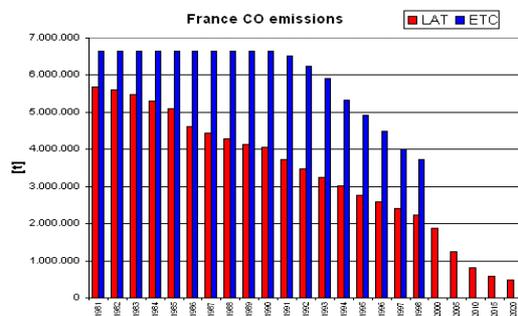
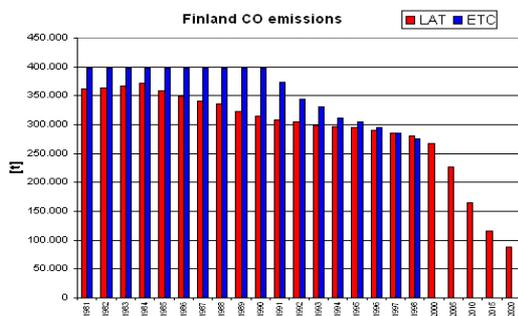
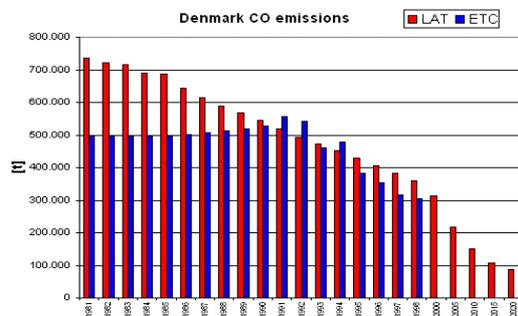
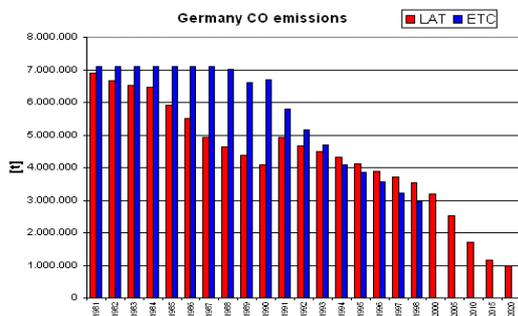
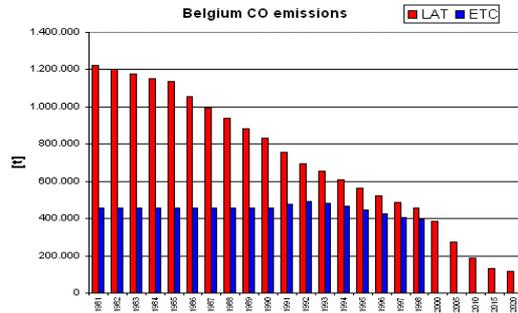
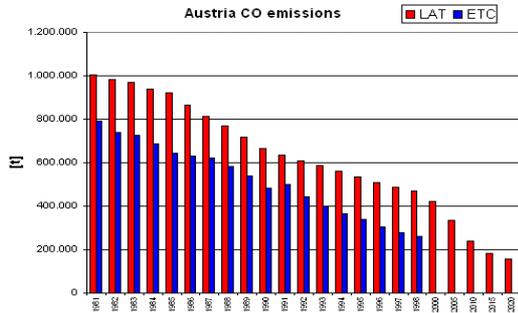


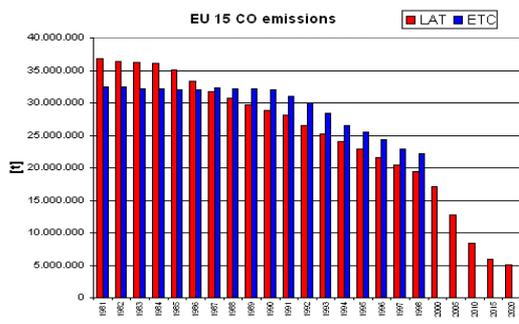
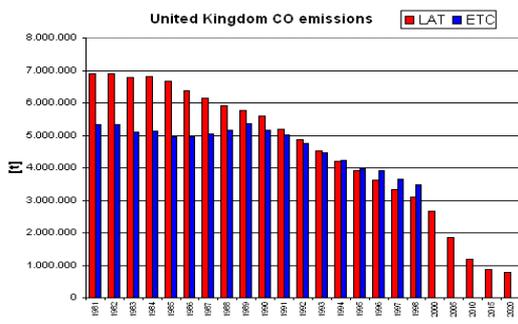
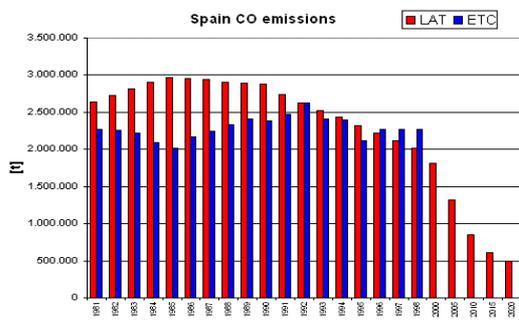
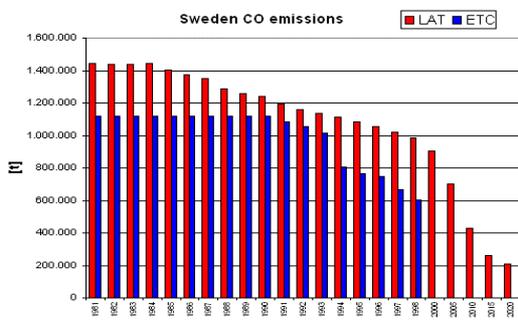
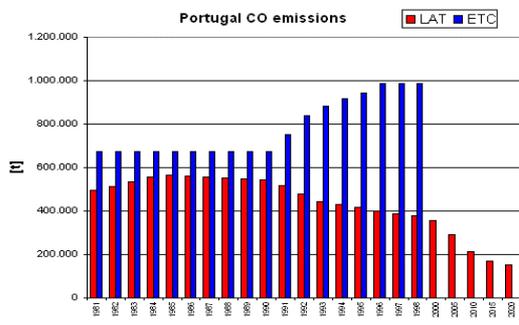
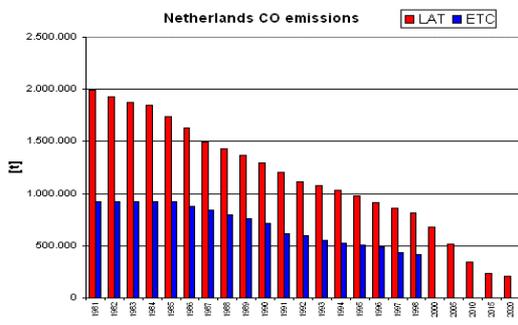
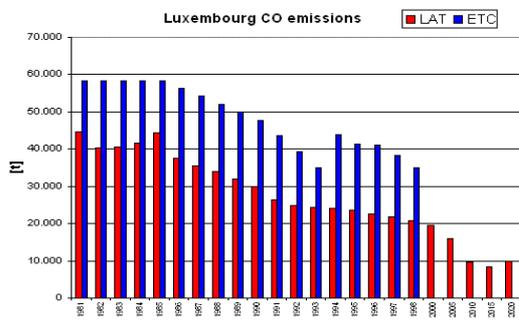
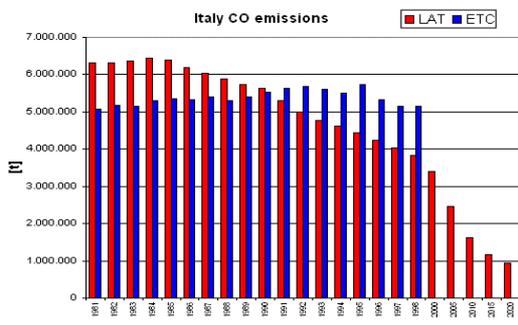


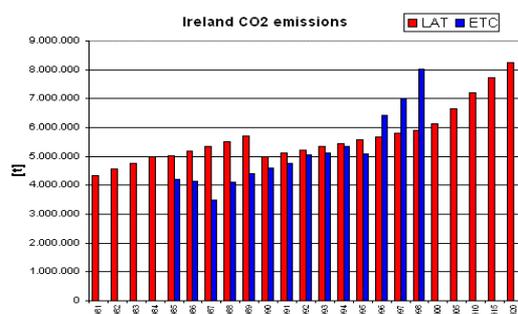
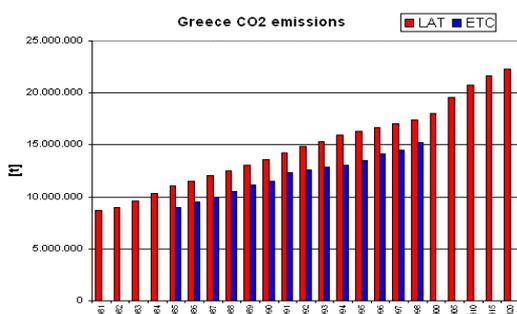
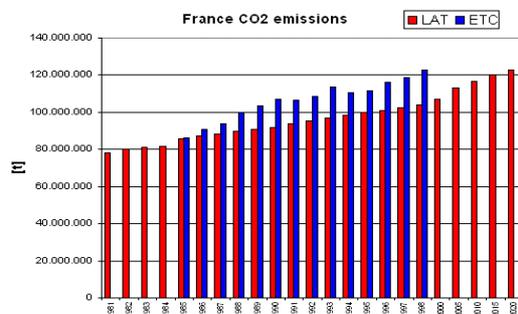
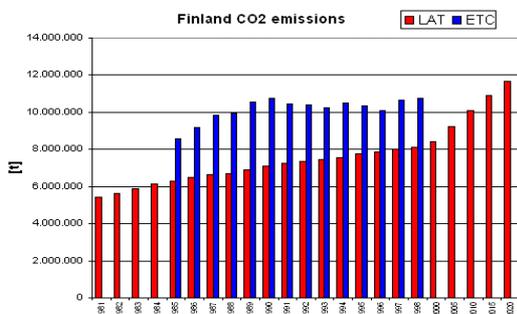
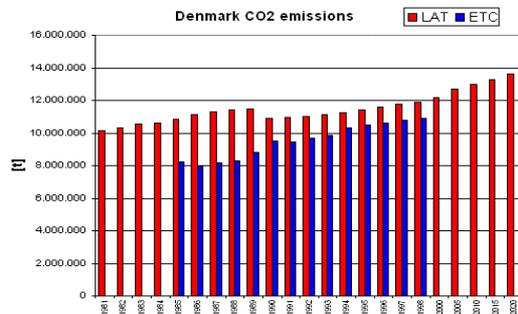
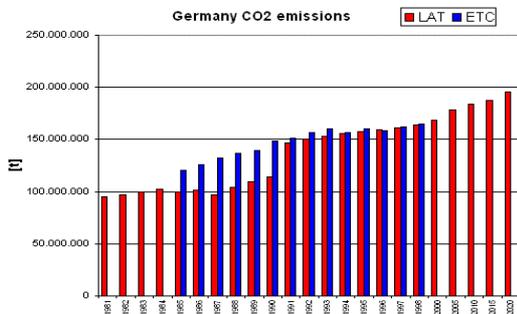
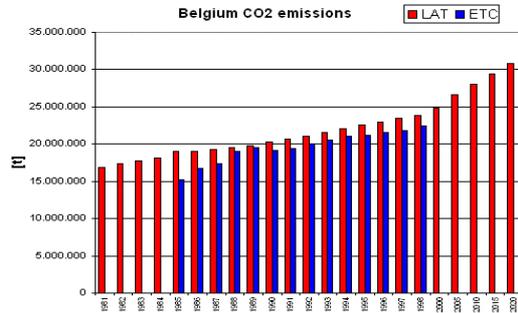
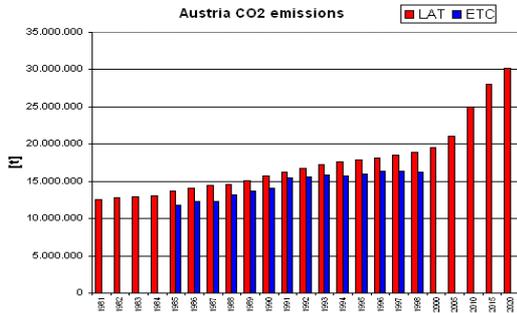
8.3. Comparison of estimates (Copert/LAT and national data available at ETC)

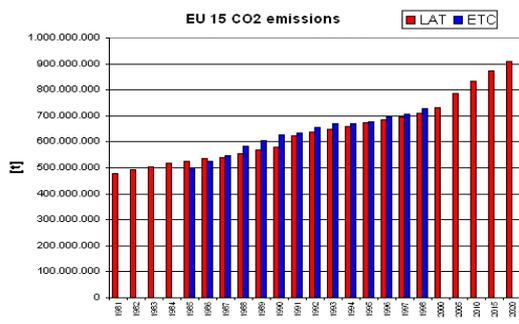
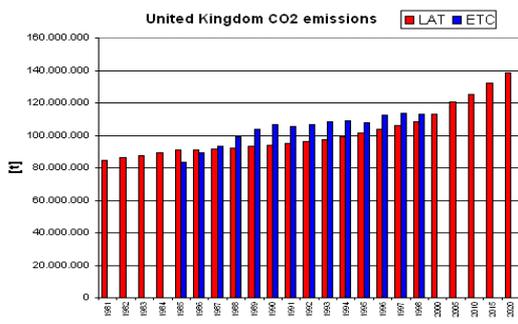
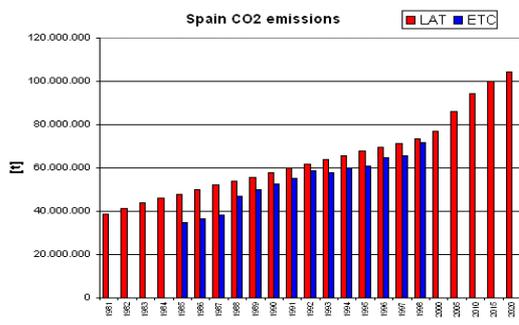
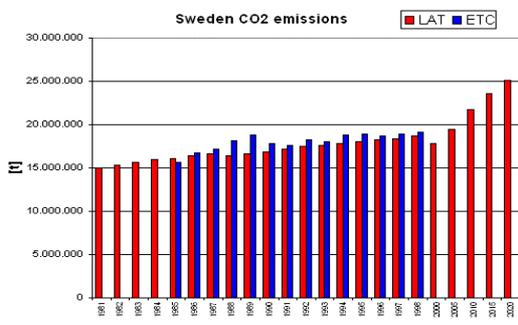
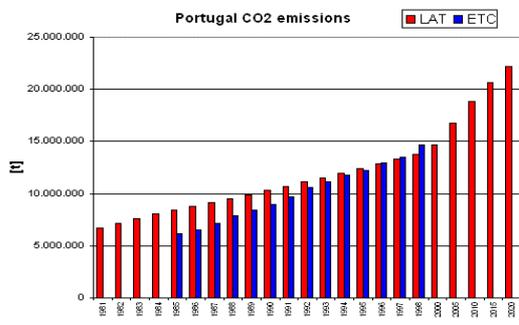
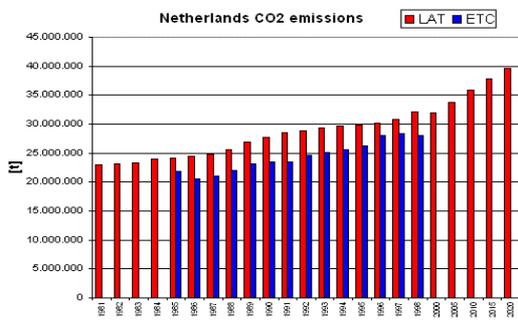
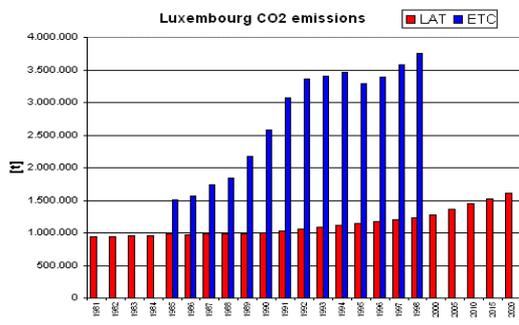
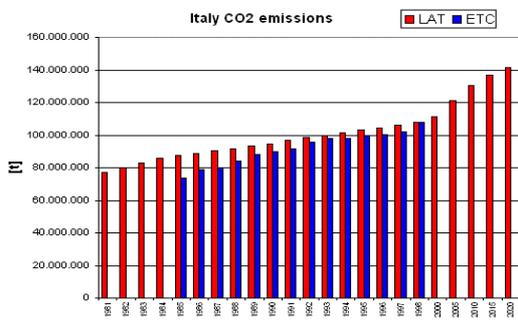


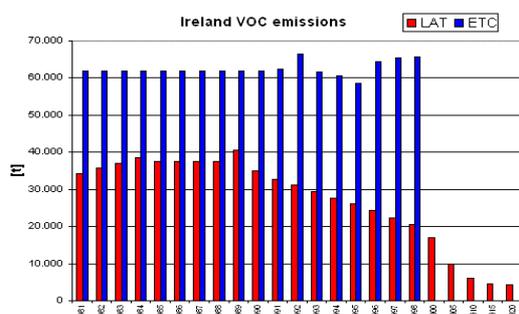
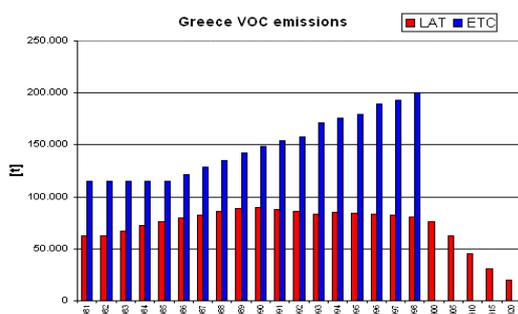
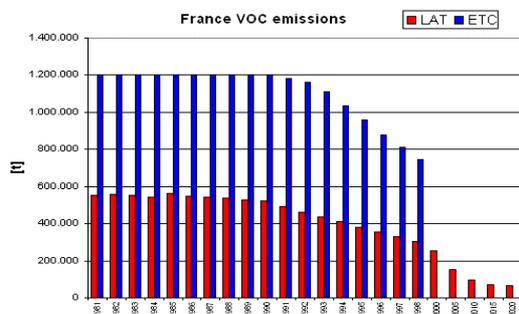
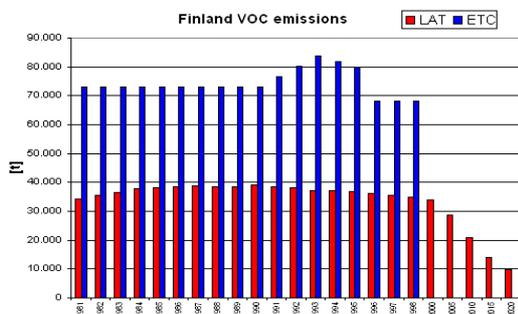
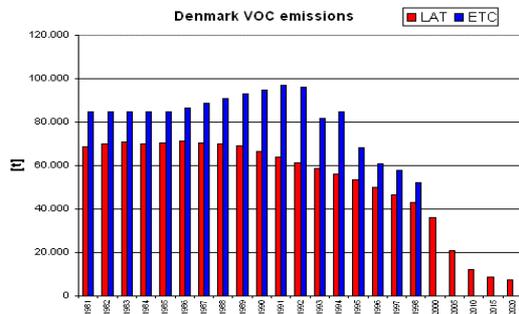
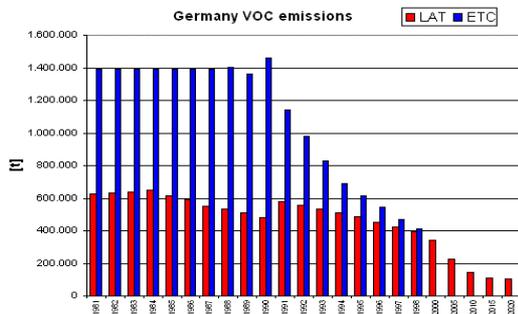
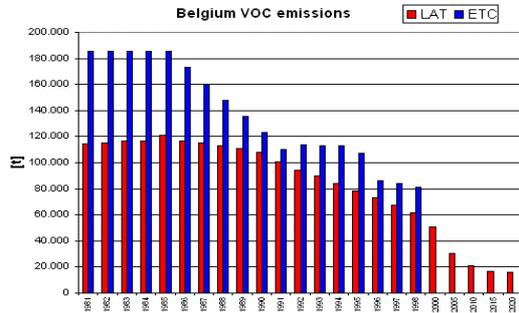
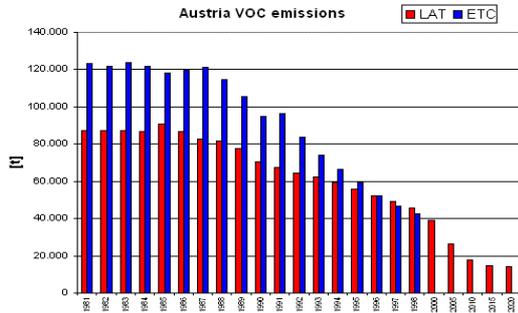


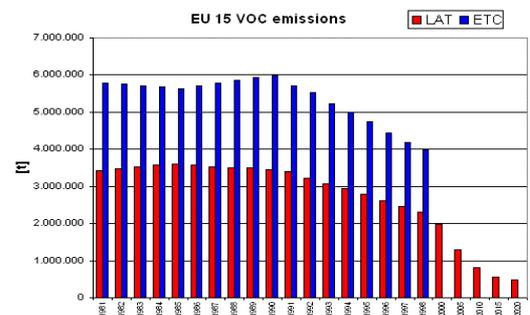
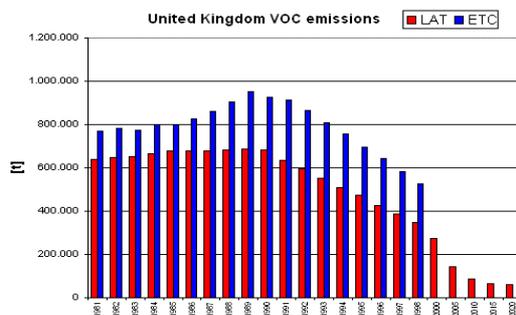
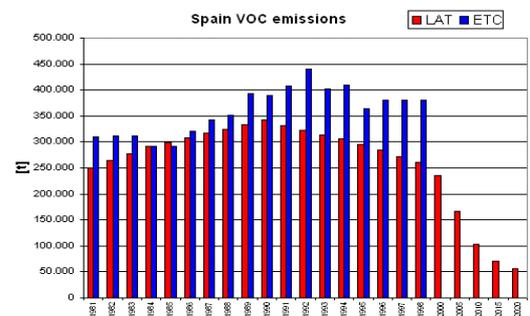
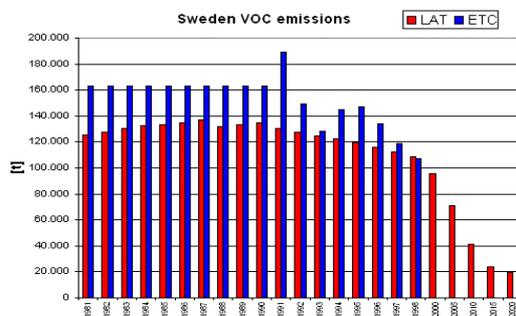
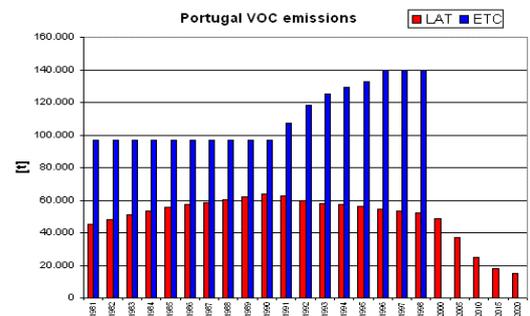
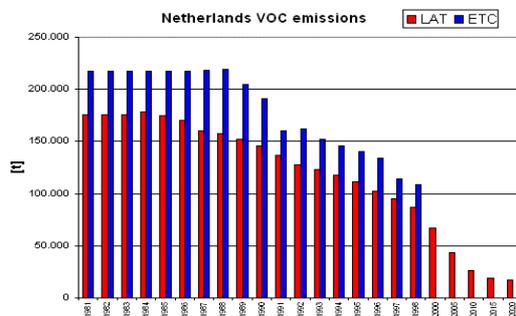
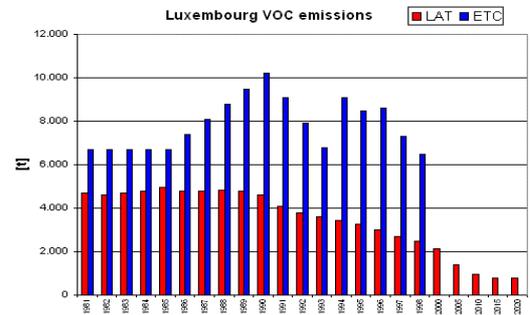
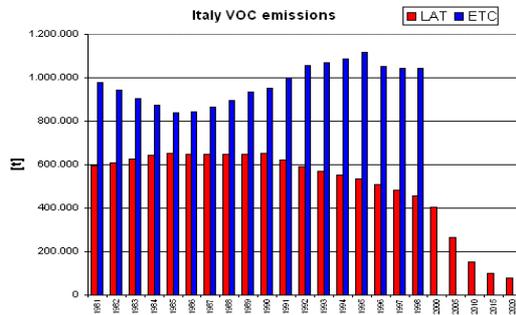






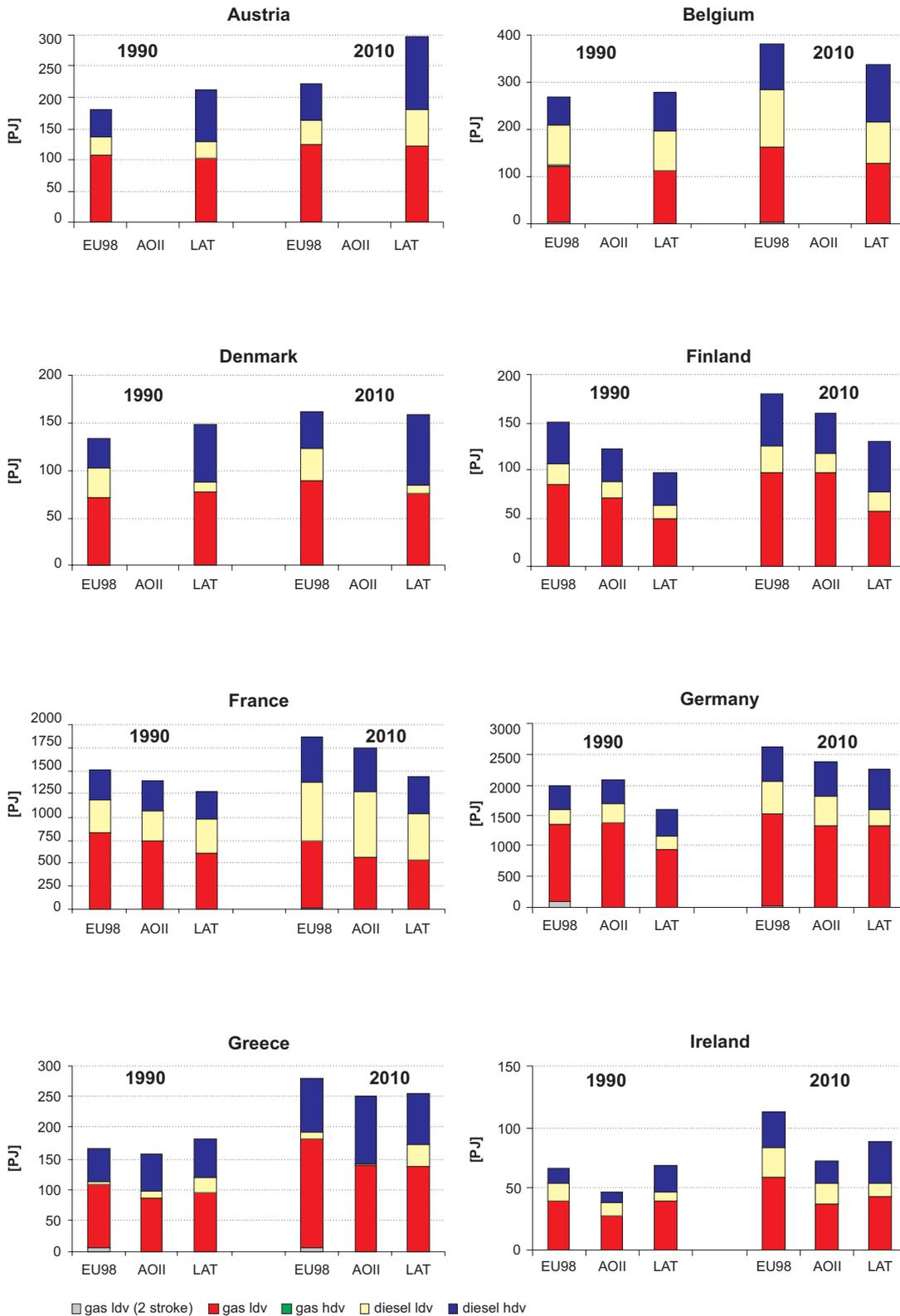


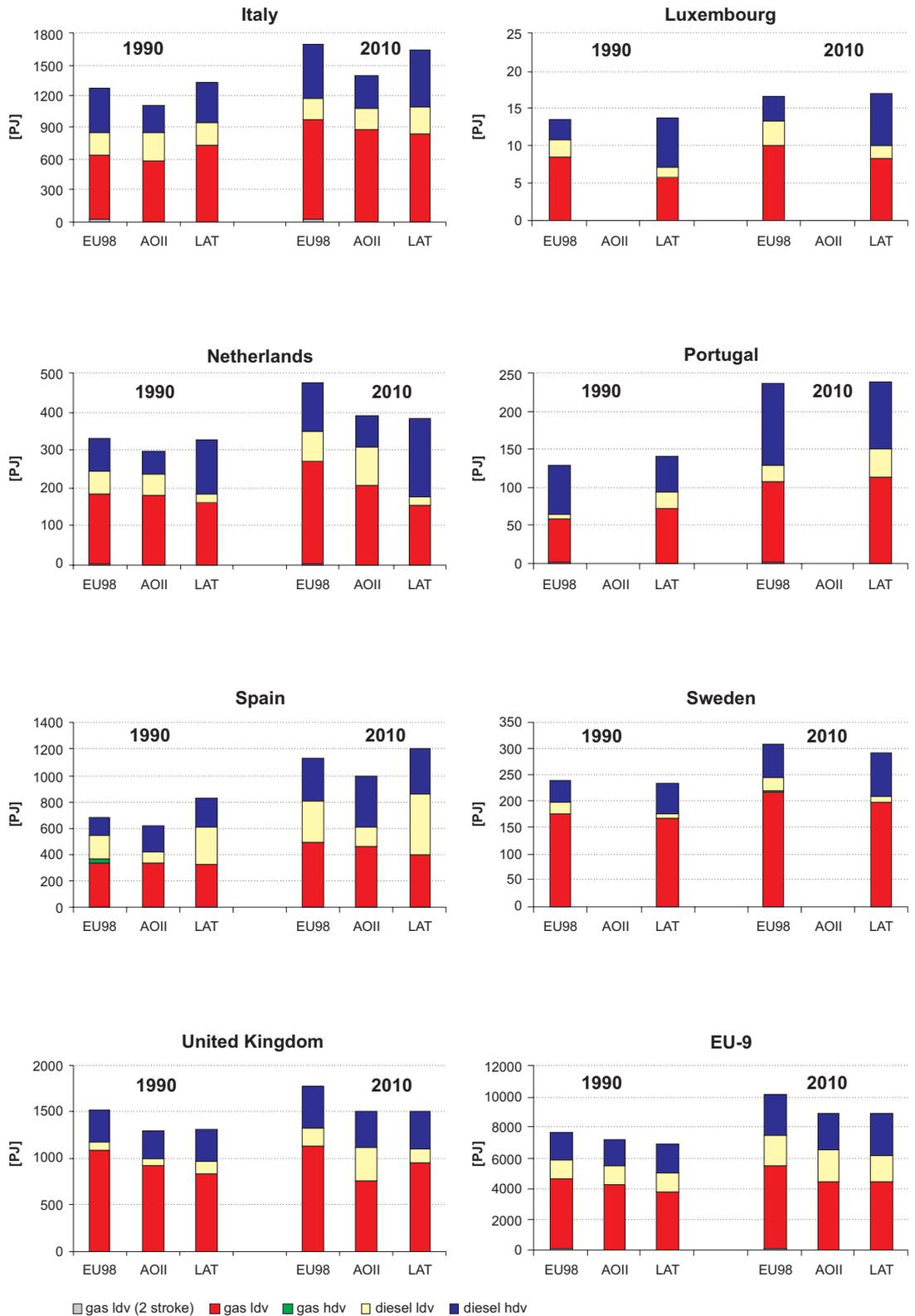




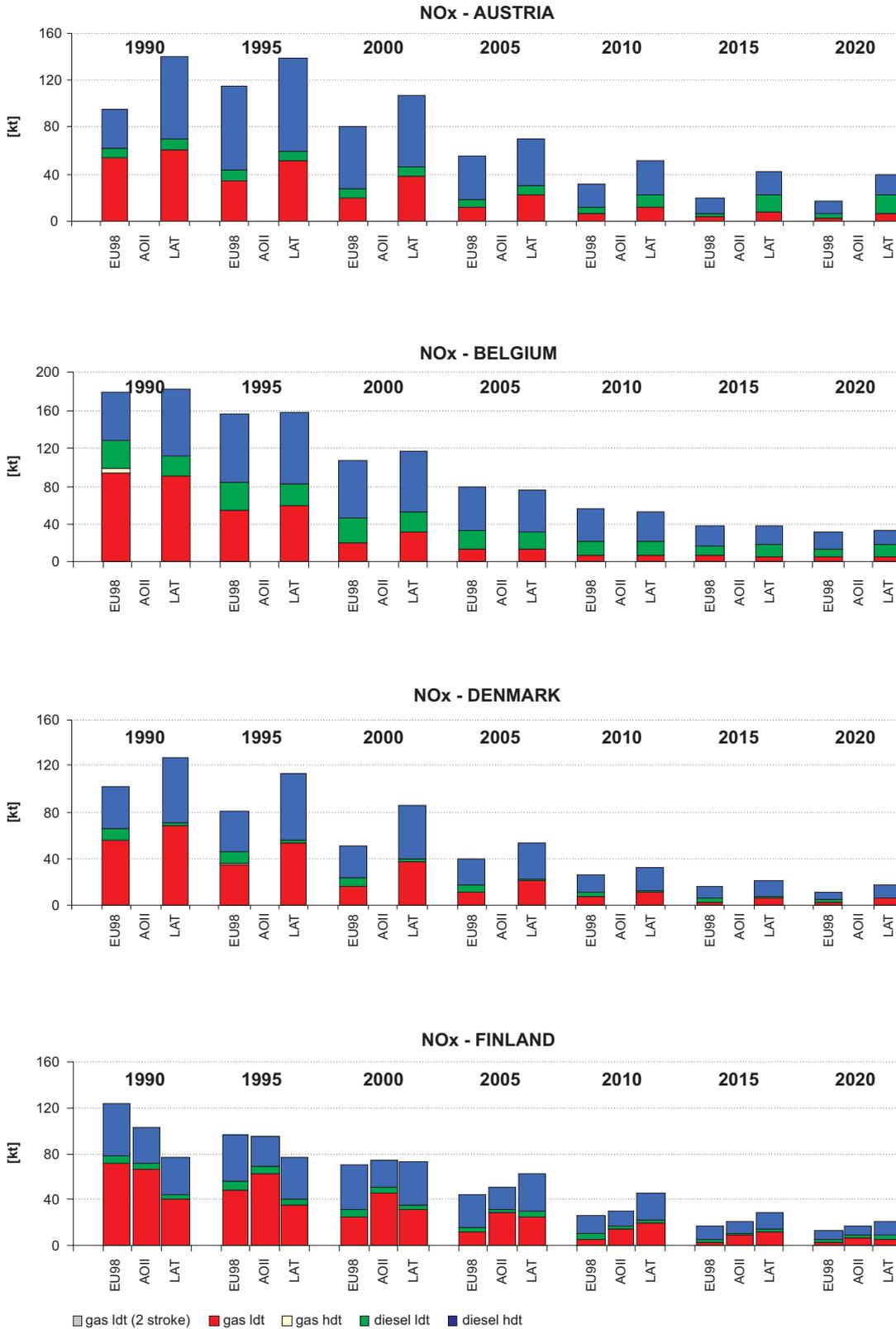
Note: Central VOC emission estimates presented in this annex stand for exhaust emissions alone

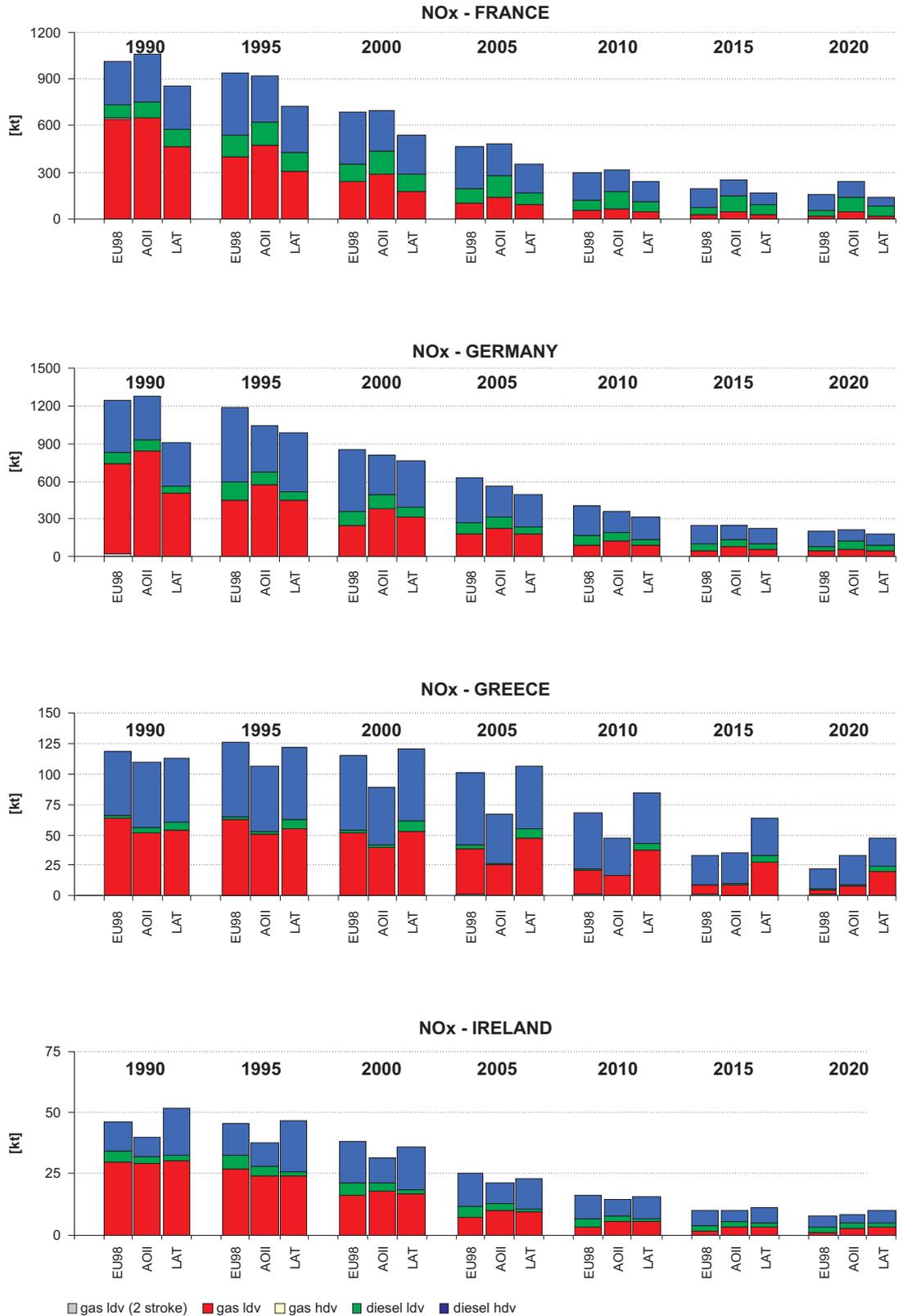
8.4. Comparison of fuel consumption estimates between RAINS (ShAIR/EU 1998), Tremove (AOII) and ForeMove (LAT)

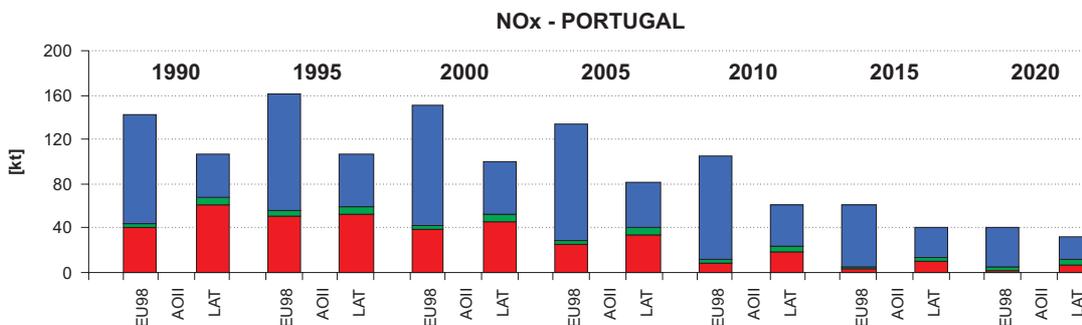
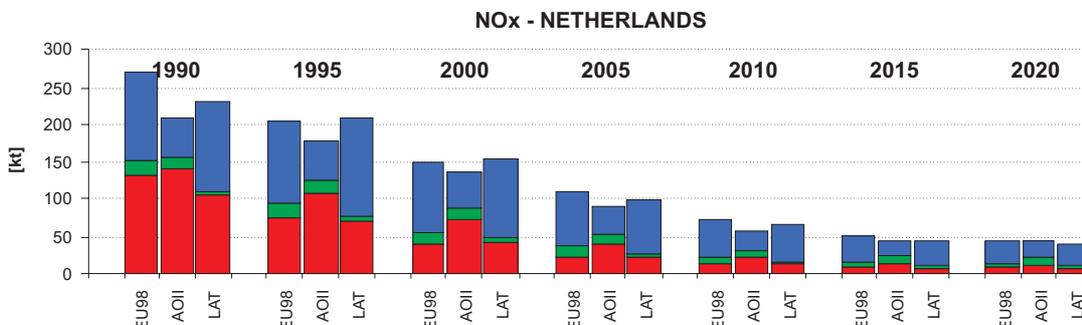
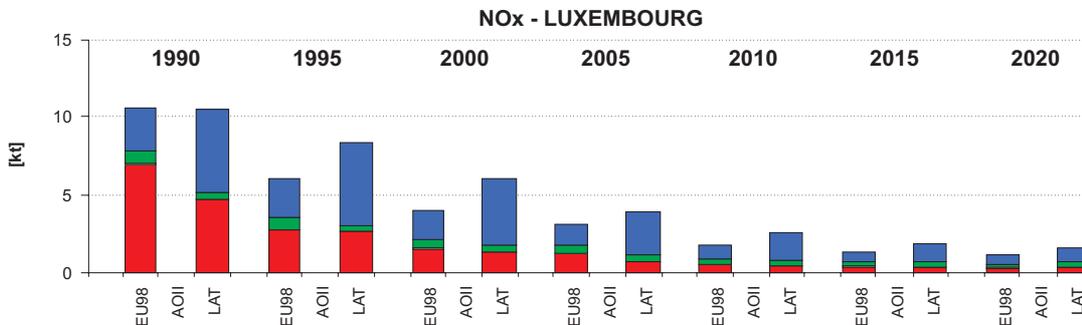
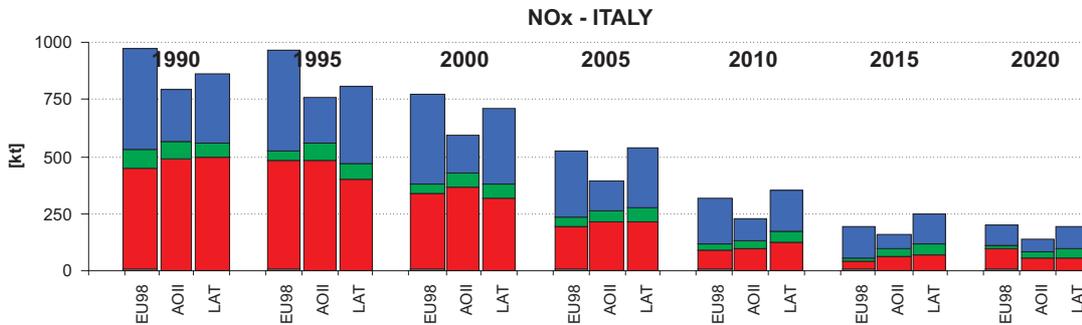




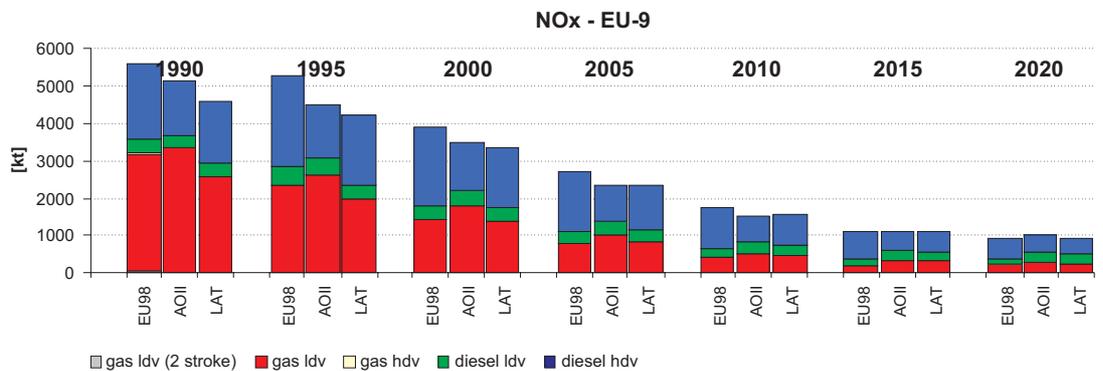
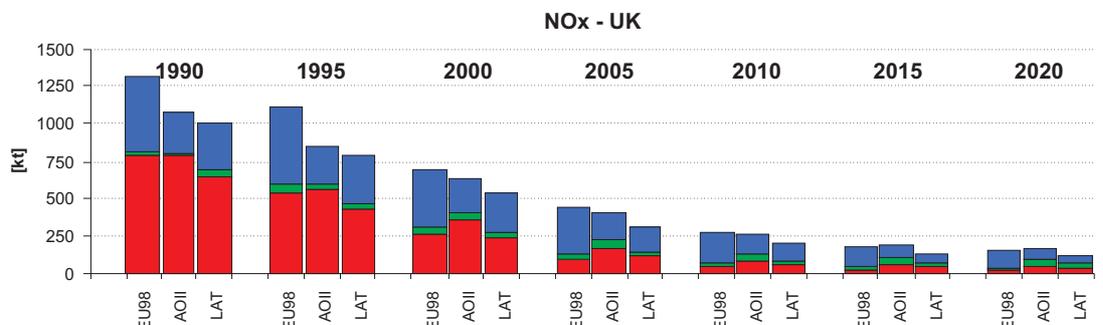
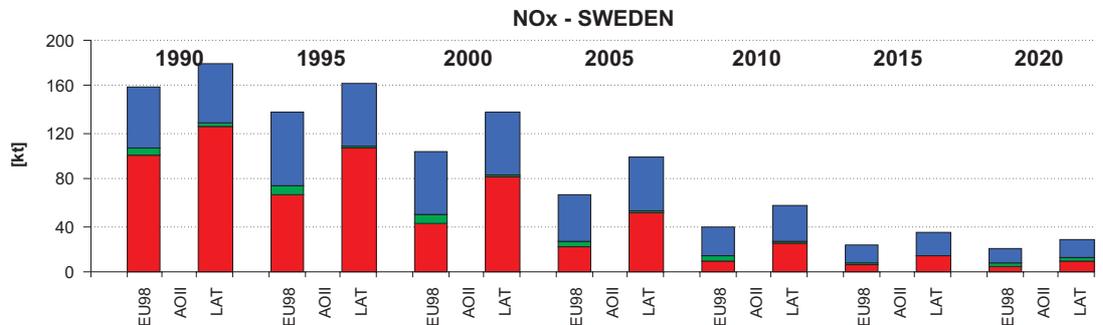
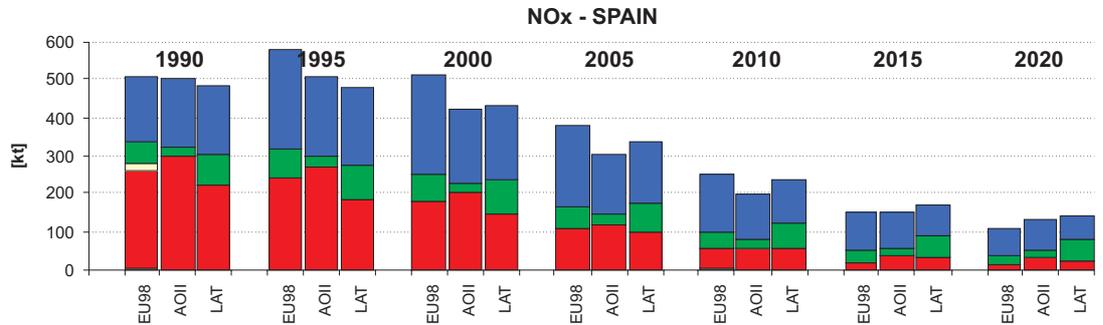
8.5. Comparison of emission estimates between RAINS (ShAIR/EU98), Tremove (AOII) and ForeMove (LAT)



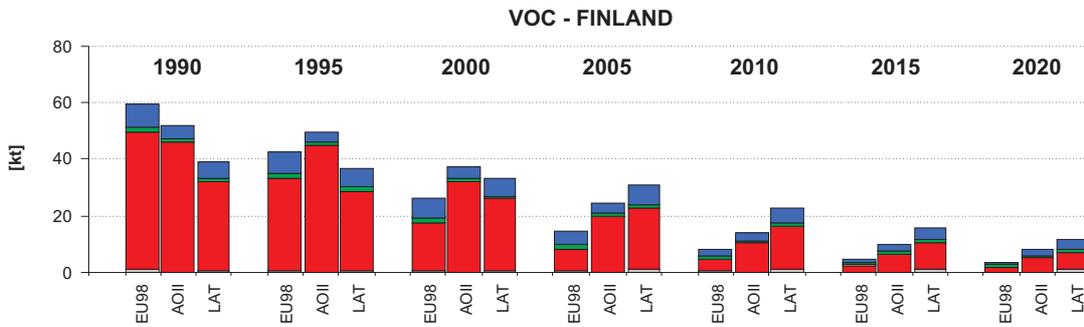
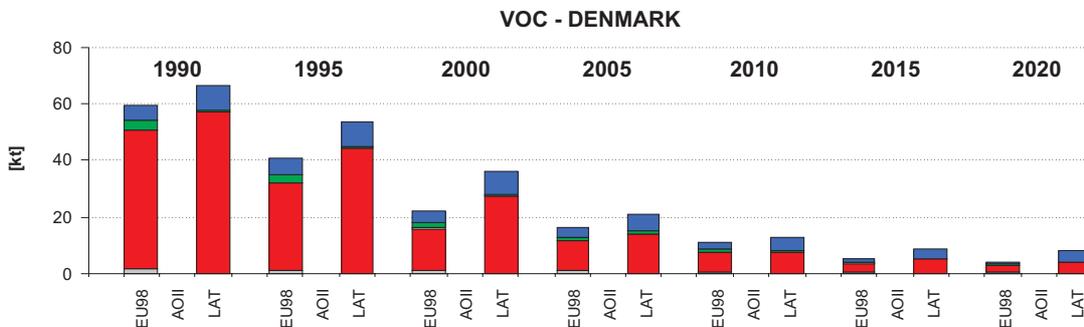
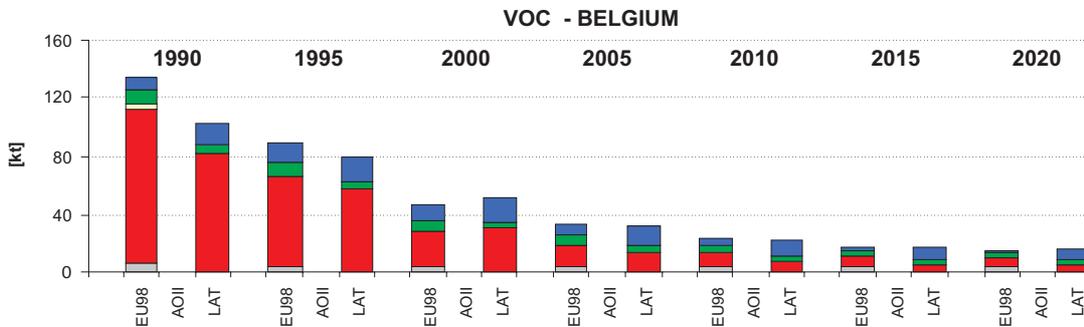
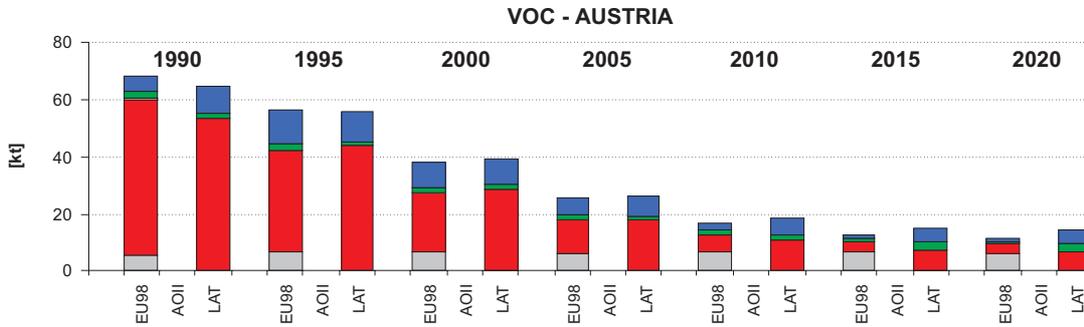




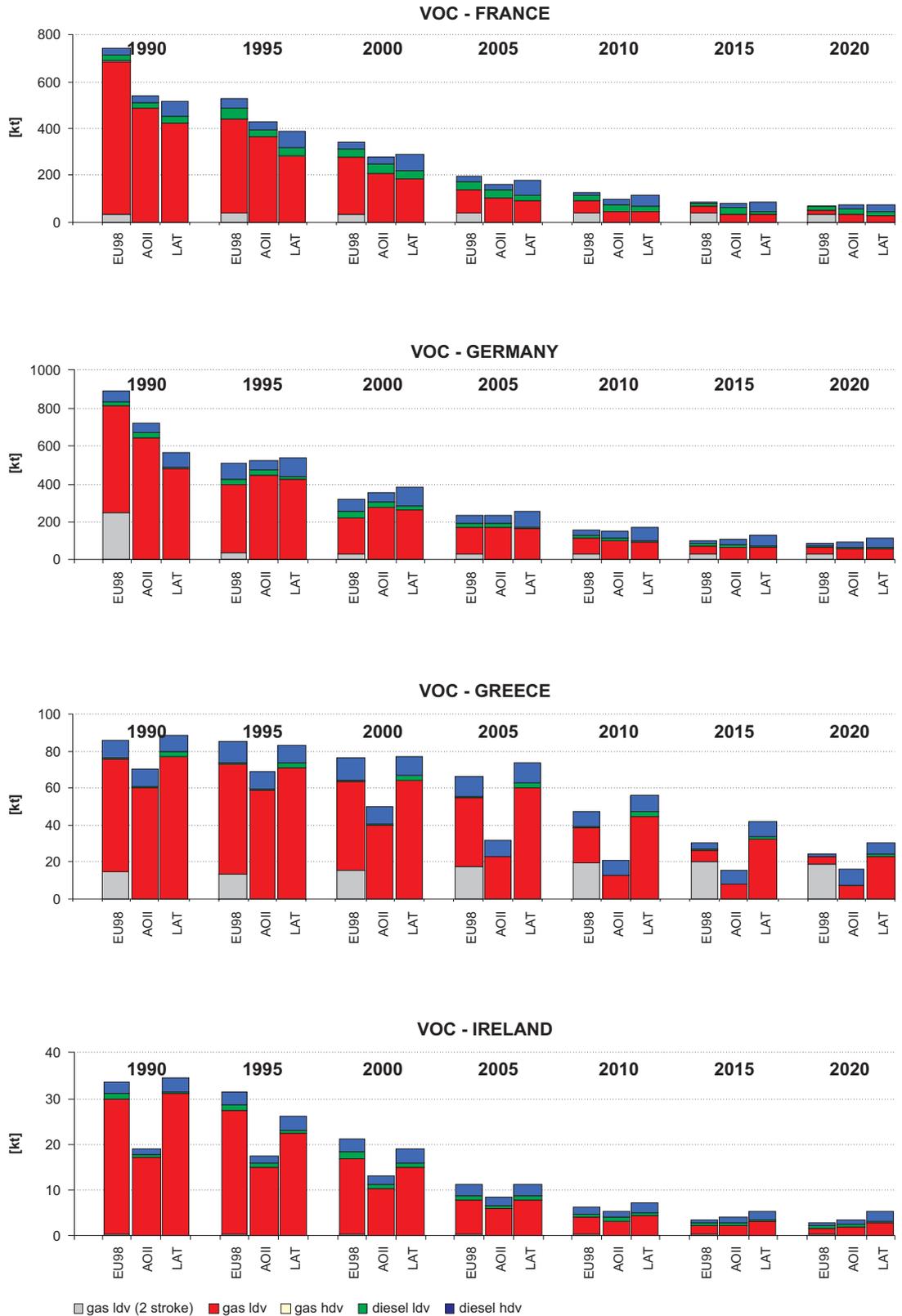
█ gas ldv (2 stroke)
 █ gas ldv
 █ gas hdv
 █ diesel ldv
 █ diesel hdv

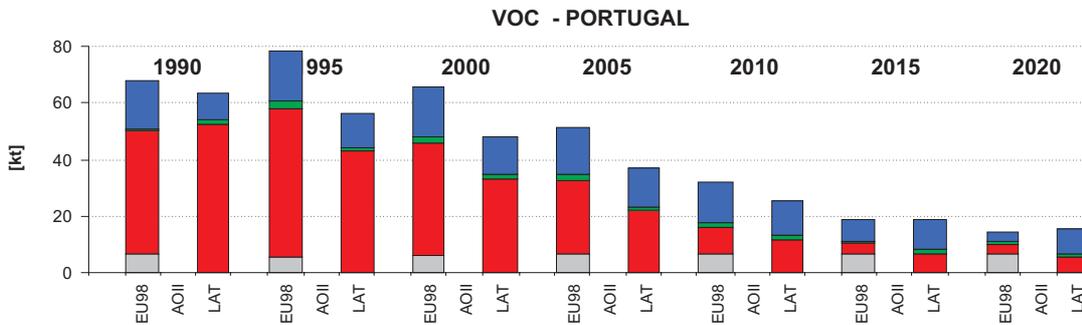
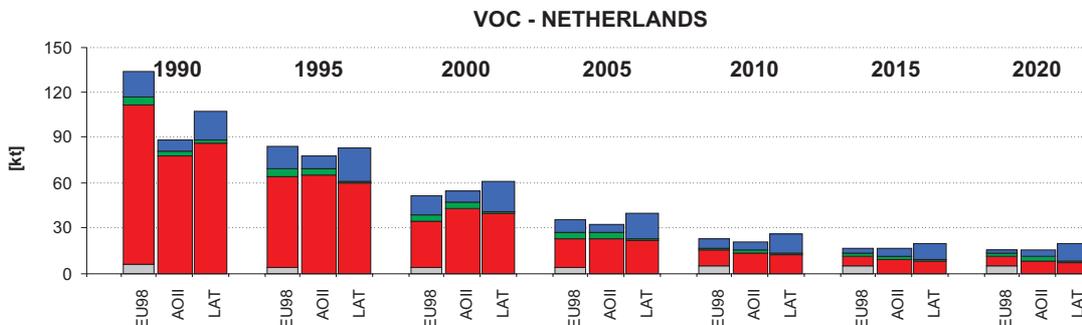
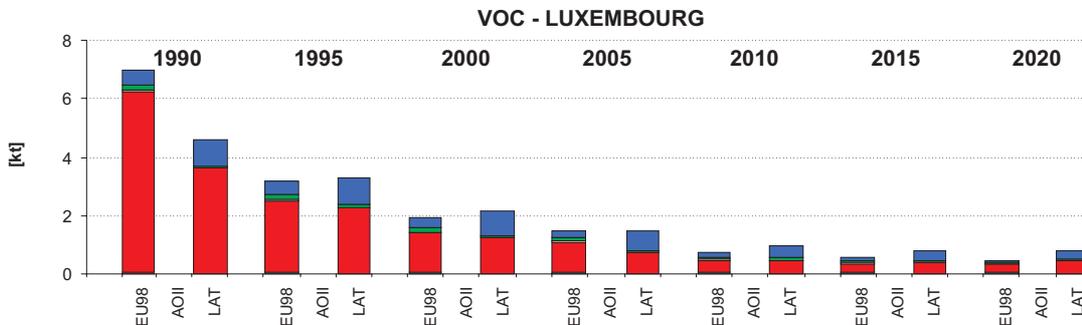
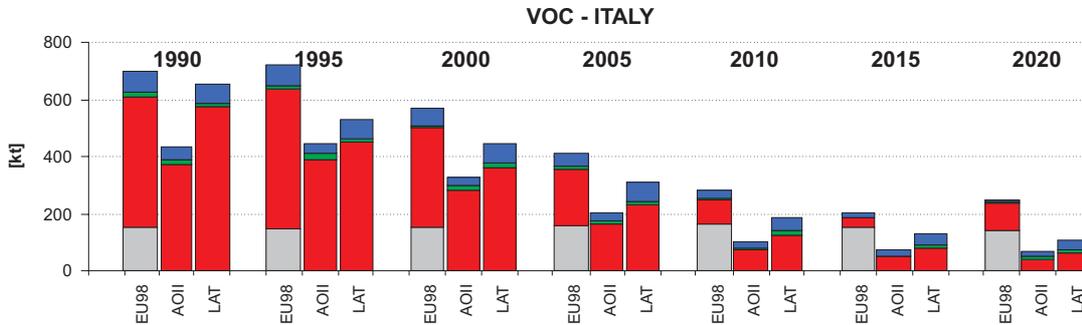


■ gas ldv (2 stroke)
 ■ gas ldv
 ■ gas hdv
 ■ diesel ldv
 ■ diesel hdv

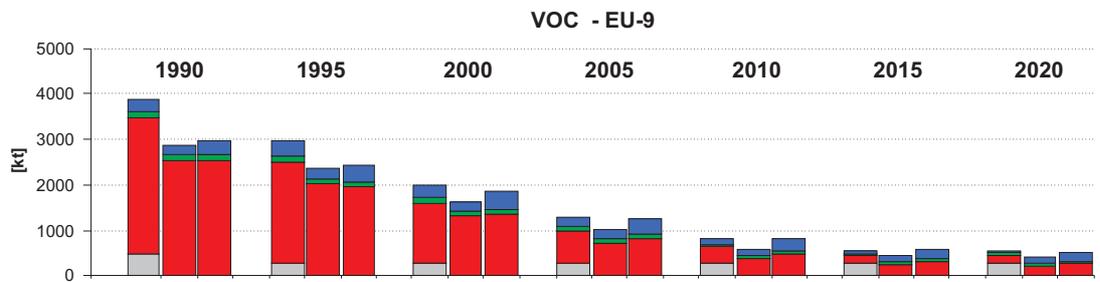
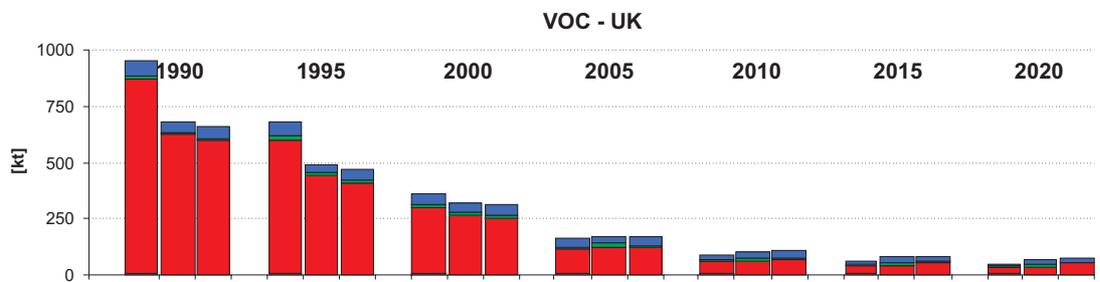
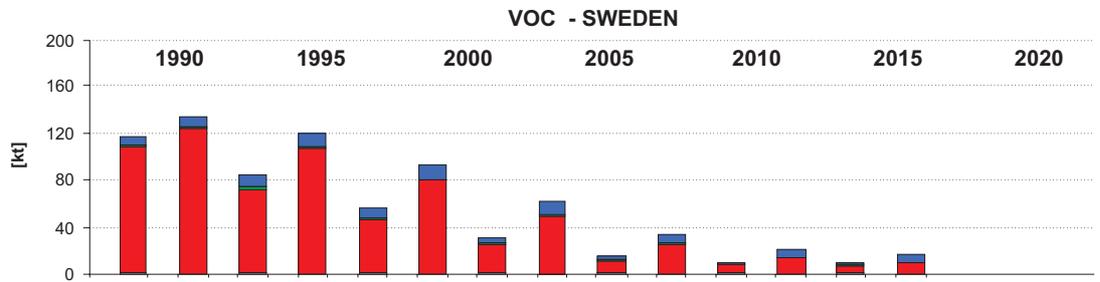
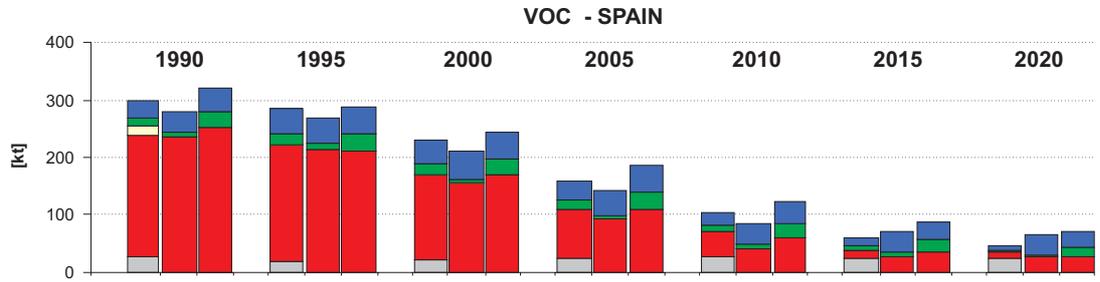


gas ldt (2 stroke) gas ldt gas hdt diesel ldt diesel hdt





■ gas ldv (2 stroke)
 ■ gas ldv
 ■ gas hdv
 ■ diesel ldv
 ■ diesel hdv



gas ldv (2 stroke) gas ldv gas hdv diesel ldv diesel hdv