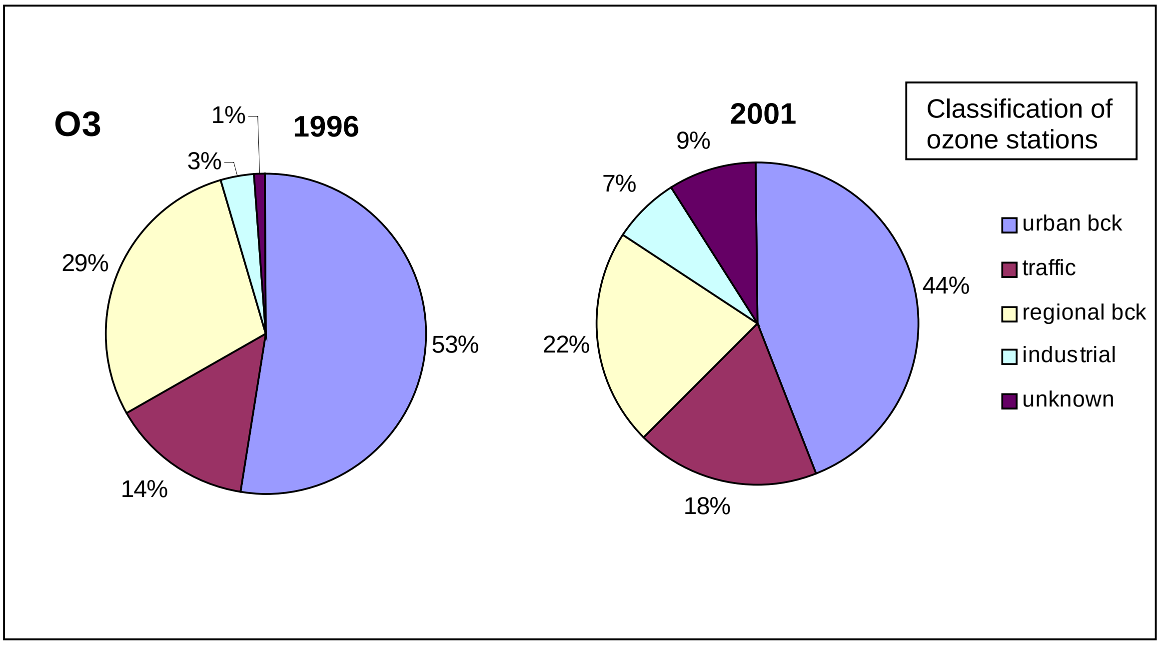
Density of air quality monitoring networks in EU15 countries during the period 1996-2001



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Front page: Classification of ozone stations in 1996 and 2002; see also Figure 2.

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SUMMARY

In the Framework Directive (96/62/EC) and its related daughter directives requirements on the number and siting of air quality monitoring stations is given. It has been suggested that, caused by introduction of the Framework Directive, there is a tendency in air quality monitoring networks towards more urban and less regional background stations. This question is analysed using the information collected under the Exchange of Information Decision and stored in AIRBASE. The situation before and after implementation of the Framework Directive and related daughter directives is analysed by comparing the situations in 1996, 1999 and 2001. In this period an increase in the number of station is seen but, in relative terms, there has been no changes from less rural background station in favour of more urban background stations.

At the end of 2001, the monitoring networks for SO_2, NO_2 PM_{10} and lead must have been brought inline with the requirements from the 1st Daughter Directive. Compliance of the networks with the monitoring requirements in 2nd and 3rd Daughter Directive must be realised before end 2002 and 2003, respectively. A further adaptation of networks can not be excluded.

Differences in monitoring strategy and network design between the Member States are visualised by comparing station densities in the various countries. A number of socio-economical and environmental variables are used to express the station density. A large variation in densities is observed. The introduction of the Framework Directive seems not to result in a notable harmonisation of the air quality networks in EU Member States after 1999; this might well be related to the fact that the period 1999-2001 is too short for the reconstruction and/or adaptation of the monitoring networks.

Contents

1. INTRODUCTION

At several occasions like meetings of the Working Group on Implementation and of the EMEP Task Force on Monitoring and Measurements it has been suggested that, caused by the introduction of the Framework Directive (EC, 1996) and its Daughter Directives (EC, 1999; EC, 2000; EC, 2002), there is a tendency in the air quality monitoring networks towards more urban and less regional background stations.

The following points support the assumption that there is a shift towards more urban monitoring stations:

- not for all pollutants in the first three Daughter Directives a limit or target value for protection of vegetation or ecosystems has been defined. For these pollutants (PM_{10}, Pb, CO, benzene) there is no requirement for establishing regional background stations;
- the requirements on number of stations used to assess compliance with health related limit values are more stringent than is the case for vegetation or ecosystem related limit values. According to the 1st and 2nd Daughter Directive the required station density is, in the highest assessment regime, at least 1.5 station per million inhabitants; only when the population in an agglomeration exceeds 6 million a lower density is required. With a EU15 averaged population density of more than 100 persons per km^2 this corresponds roughly with a station density of one station per 6700 km^2, that is three time more than the highest required density for assessment of exposure of vegetation (1 station per 20 000 km^2);
- the Daughter Directives introduce a bias towards more stations in more polluted (in general terms, urbanised) areas: when concentrations exceed the upper assessment threshold the required minimum number of stations is twice as high as when concentrations are between upper and lower assessment thresholds;
- according to the preliminary assessment reports for the 1st Daughter Directive (EC/DGEnv, 2002), in many countries it was decided to change the existing network to some extent. Often the number of stations was changed; when changed, it was usually increased. In some countries stations were relocated. Some relocations were only slight, in order to comply with the micro-siting requirements. Other relocations were macro-siting changes in order to improve the balance between station types in the network.

In relation to this question, it has also been questioned whether the introduction of the Framework Directive has initiated some *harmonisation* in monitoring strategies in the EU Member States. An analysis (De Leeuw *et al.*, 1999) of the ozone networks operational in the Member States under the former ozone directive (EC, 1992) showed that there are large differences in network design between the Member States. As a consequence of the Framework Directive, which gives criteria on the number and siting of monitoring stations, one may assume that these common principles for monitoring strategy result in smaller differences in station density.

In this note both questions are addressed using information available from AIRBASE, that is, using the information submitted under the Exchange of Information (EoI) Decision (EC, 1997; EC, 2001). Although the EoI should cover at least all stations "*which are used in the framework of the implementation of directives adopted in accordance with Article 4 of the Directive on air quality*"[1], there is no guarantee that this is indeed the case. A preliminary comparison between stations included in the questionnaire on the first Daughter Directive and stations reporting under the EoI

[1] See Article 3 of the Exchange of Information Decision.

indicates a mismatch of about 30% between both station sets (Van den Hout, personal communication).

For evaluation of any change in networks, three years have been selected:

- **1996**: this year should represent the situation before adoption of the Framework Directive. 1996 has been selected, as this is the first year for which AIRBASE contains information for the majority of EU15 Member States. It should be mentioned, however, that for a number of Member States 1996 data is incomplete or missing. Although the EoI Decision requires that Member States submit additional information over the period 1990-1997, this is not always realised. Missing information for some Member States in 1996 hampers the comparison between the years.
- **1999**: the Framework Directive is adopted, the first daughter directive on SO_2, NO_2, particulate matter and lead enters into force. Member states have to bring their monitoring networks in line with the requirements of the 1st Daughter Directive.
- **2001**: the most recent year available in AIRBASE. Medio 2001 monitoring networks must comply with the 1st Daughter Directive requirements.

In this note the monitoring situation with respect to SO_2, NO_2, PM_{10}, CO and O_3 is discussed. The 2nd Daughter Directive (on CO and benzene) and 3rd Daughter Directive (on ozone) must be implemented by December 2002 and September 2003, respectively. For these pollutants the 2001 situation will not represent the “final” stage.

2. DATA COLLECTION

2.1. STATION INFORMATION

For each of the three years, all stations, which have submitted raw data, have been selected from AIRBASE. No further selection criteria on data capture has been applied resulting in an upper limit of the number of operational stations. In practical applications a number of stations will not pass the test on data coverage of 75 or 90%. For 1996 information from several Member States (3 to 6, depending on the pollutant) is missing; for 1999 and 2001 for all Member States with exception of Luxembourg information is available.

Following the EoI, stations are classified according to a *type of area* and a *type of station*. The type of area defines the wider surroundings of the station:

urban	Station is located in a city;
suburban	Station is located on the outskirts (fringe) of a city, or in small residential areas outside the main city;
rural	Station is located outside a city.

The type of station is defined in relation to the dominant emission sources influencing the concentration at the station. The following types of station have been defined:

Traffic	Station located such that its pollution level is determined predominantly by the emissions from nearby traffic (roads, motorways, highways);
Industrial	Station located such that its pollution level is influenced predominantly by emissions from nearby single industrial sources or industrial areas with many sources;
Background	Station located such that its pollution level is not influenced significantly by any single source or street, but rather by the integrated contribution from all sources upwind of the station.

Note that each type of area can be combined with each type of stations, for example the combination urban/traffic and suburban/traffic defines a street-station in the (inner)city; the combination rural/traffic defines a station close to a intercity motor- or highway.

According to the EoI submission on the type of area is mandatory; information on type of station should be provided "to the extend possible". In our view (Buijsman *et al.*, 2003), however, both items provide information essential for a proper evaluation of the observed concentrations. The need for information on both points can, in the best way, illustrated with an example: Figure 1 gives the annual mean NO_2 concentration at two stations in Berlin. Both stations are by their type of area classified as *urban*; the distance between the two stations is less than 4 km. The marked difference in behaviour - at Charlottenburg concentrations are systematically higher and a stronger decreasing trend is observed - can only be explained by the type of station. Charlottenburg is a *traffic-urban* station while Neuköln is a *background-urban* station.

Based on type of area/type of station combination all stations have been grouped into four classes according to the scheme given in Table 1. In the remaining of this paper station are indicated by their class unless explicitly stated.

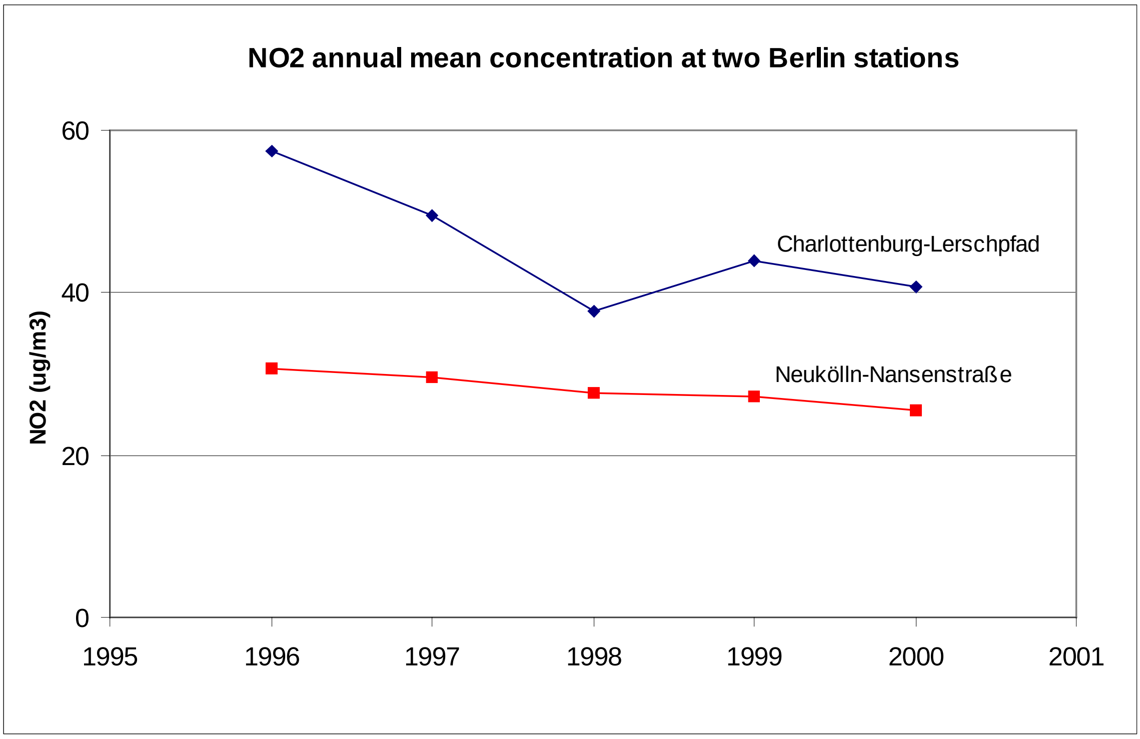


Figure 1. Annual mean NO2 concentration at two stations in Berlin.

Table 1. Classification scheme of stations based on type of area and type of zone.

class	Type of area	Type of station
(sub)urban background	urban	background
	suburban	background
traffic	urban	traffic
	suburban	traffic
	rural	traffic
	unknown	traffic
regional background	rural	background
industrial	urban	industrial
	suburban	industrial
	rural	industrial
	unknown	industrial
unknown	unknown	background
	urban	unknown
	suburban	unknown
	rural	unknown
	unknown	unknown

2.2. PROXY VARIABLES

The question whether the introduction of the Framework directive initiated some harmonisation in monitoring networks, can not be answered by simply looking at the number of stations. The socio-economical and pollution situation differs so widely over the Member States that other explaining factors than simple total station numbers must be included. Here we will use the variables given in Table 2 to compare number and type of stations in the Member States. In the analysis we have neglected the changes of the proxy variables over the period 1996-2001. In all case the most recent available data (1999 or 2000) has been used. All data is available at the EEA data warehouse, see for more detailed information Larssen *et al*, 2003.

Variable	source
Total population	World Bank, World Development Indicators 2002
Urban population	World Bank, World Development Indicators 2002
Total area	Eurostat, New Cronos
Gross Domestic Product (1995 market prices)	Eurostat, New Cronos
Total emissions (SO_2, NO_x, NMVOC, CO)	National submissions to CLRTAP/EMEP
Total (primary + secondary)emissions PM10	CLRTAP data completed with AutoOilII and CEPMEIP totals
Energy consumption by road traffic	International Energy Agency: Energy Balances OECD countries

3. CHANGES IN STATION CLASSIFICATION

For the EU the relative distribution per station class is for all year given in Figure 2. Although for each of the pollutants the absolute number of stations increases sharply (for PM_{10} with 1900%, for CO with 650% and the other pollutants with 130%), the changes in distribution over the station classes are limited.

In general the largest changes are seen between 1996 and 1999. Partly these changes will be caused by the ill representativity of the 1996 data. As mentioned above, for some (large) Member States no information is available. Large changes are particularly observed for PM_{10}, however, the 1996 data is not representative as in most countries a systematic monitoring of PM_{10} started around 1996. For typically traffic-related pollutants (NO_2, PM_{10}, CO) a large fraction of traffic stations can be seen.

The assumption that the directives introduced a shift towards more (sub) urban stations is not supported by the AIRBASE information. In absolute terms, there is an increase in the number of urban stations. However, the available data indicates a small decrease in the percentage of urban background stations. However, as the fraction of unclassified stations has increased as well, it might well be that the number of urban background stations is underestimated over the last years.

Similarly, no conclusions can be drawn with respect to the fraction of regional background stations. The small changes between 1999 and 2001 might well be related to the fact that a two-year period is too short for a complete adaptation of a network to the requirements in the Daughter Directives.

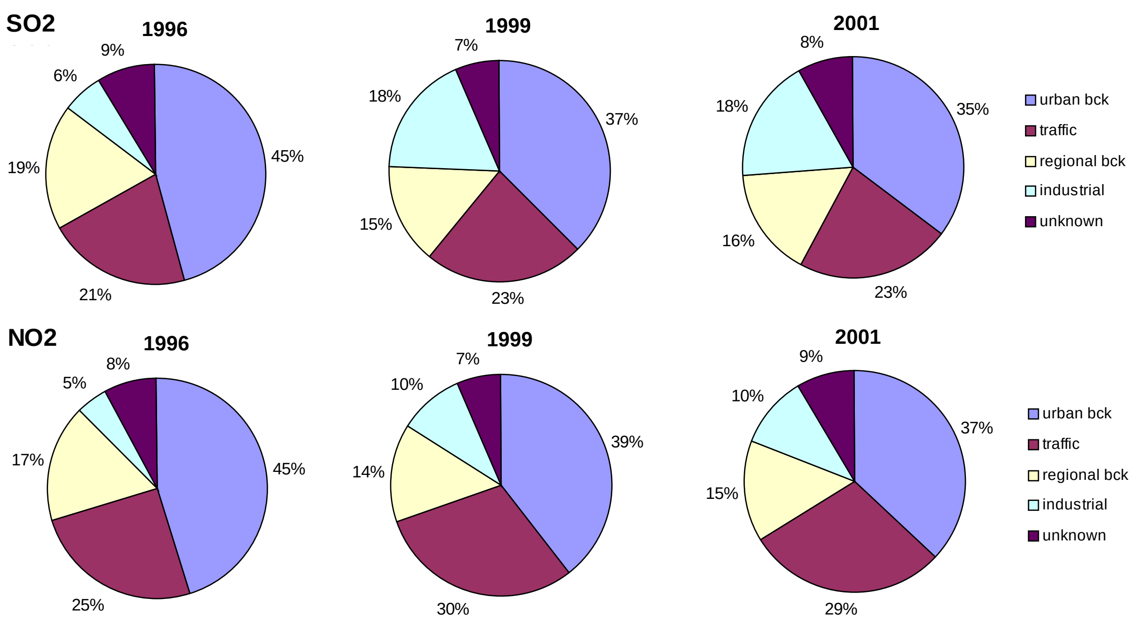
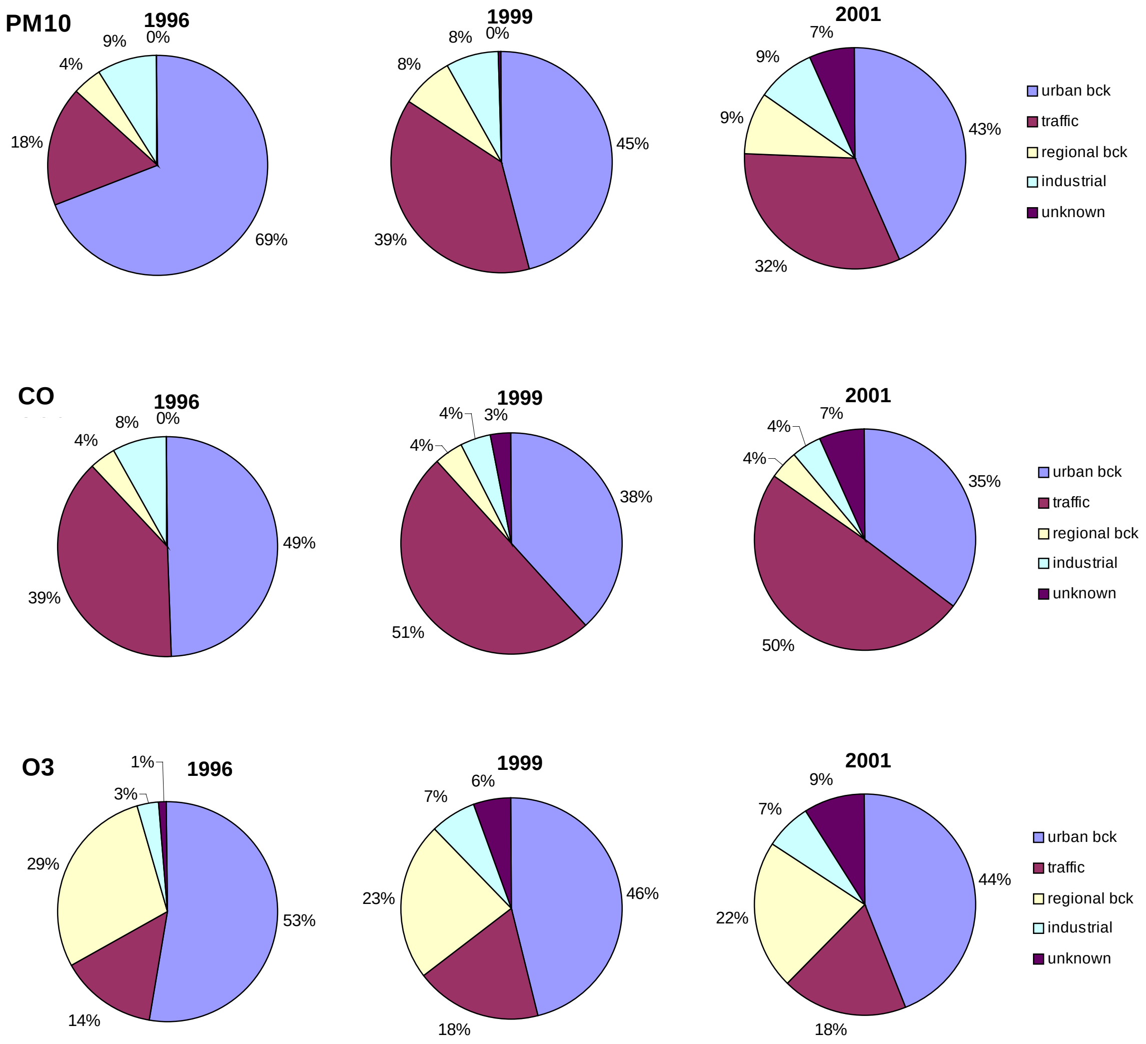


Figure 2. Distribution of station classification (SO_2, NO_2 monitoring stations) in EU Member States for the years 1996, 1999 and 2001.



Number of station	SO2			NO2			PM10	
	1996	1999	2001	1996	1999	2001	1996	1999
urban bck	343	580	605	333	592	668	31	134
traffic	158	361	385	184	452	525	8	113
regional bck	140	227	270	129	217	267	2	22
industrial	45	279	315	36	145	189	4	23
unknown	65	101	136	57	98	158	0	1
total	751	1548	1711	739	1504	1807	45	293

	CO			Ozone		
	1996	1999	2001	1996	1999	2001
urban bck	54	303	295	311	561	625
traffic	43	392	415	83	225	261
regional bck	4	34	34	170	283	316
industrial	9	35	37	20	82	98
unknown	0	24	56	7	68	127
total	110	788	837	591	1219	1427

Figure 2, continued. Distribution of station classification (PM_{10}, CO and O_3 monitoring stations) in EU Member States for the years 1996, 1999 and 2001.

4. DIFFERERENCES IN NETWORK DESIGN

Descriptions of the monitoring strategies on which Member States have designed their network are not widely available. Evaluation of harmonisation in the design phase is not possible. Here we are looking at the final results: is it possible to find common principles in network design if we relate the number and/or type of station to proxy variable which are either important driving forces or are related to the "stock at risk".

In analysing the networks as a whole, the total number of stations is expressed in economical terms (using GDP), in pollution terms (using emission) and in terms of the country size (using population data and total land area). Figure 3 shows the density of the ozone monitoring network; for the other pollutants similar graphs are given in Annex A. The figure shows that the network densities vary widely over the European Union. Over the five-year period no converging trend towards a more harmonised network density is seen. The smallest - but still large - variability is generally seen in the number of stations per capita. However, whereas the major concern focuses on pollution by ozone and PM_{10} and in lesser extend by NO_2, this is not reflected in the station densities. The EU-wide station densities of NO_2 and SO_2 (respectively, 4.8 and 4.6 station per million) outweighs the density of ozone (3.8 station per million) and PM_{10} (in 2001, 2.5 station per million but still increasing). The low number of CO stations (2.2 station per million) is in agreement with the (from a human health perspective) low priority.

According to the 1st and 2nd daughter directive there is no requirement to measure PM_{10} and CO in rural areas. Still about 9% of the PM_{10} and 4% of the CO station is classified as "rural background". From an assessment point of view these stations are important to estimate the urban contributions.

How large the difference in network design between the Member States is, can be illustrated by an example. In September 2003 EEA received a request from a Spanish journalist *"for a comparison of urban air quality in cities in Spain with those in Italy, United Kingdom, Germany, France and the Netherlands, the most up to date ozone and particulate concentrations are requested. The data is requested for each of the 6 biggest cities in each country (in the Netherlands this could be fewer)"*.

The ETC extracted the requested information from AIRBASE using the following criteria:

- 2001 data for ozone and PM_{10};
- only urban background stations (when comparing the air quality situation in different cities, monitoring stations representative for the background air pollution levels (so called urban background stations) should be used; industrial or street stations are too much influenced by local (traffic) emissions to be included in such a comparison;
- criteria for data capture is 75%, that is during more than 75% of the year valid measurements must be available;
- when more than one urban background station is available in a city, concentrations are averaged over all operational stations;
- only cities with more 200 000 inhabitants are included.

Application of these criteria resulted in no information at all for Spanish cities !! In the major cities in Spain only traffic stations are operational. A similar but not so extreme situation is found in other Member States: not for all 6 biggest cities urban background concentrartions are available.

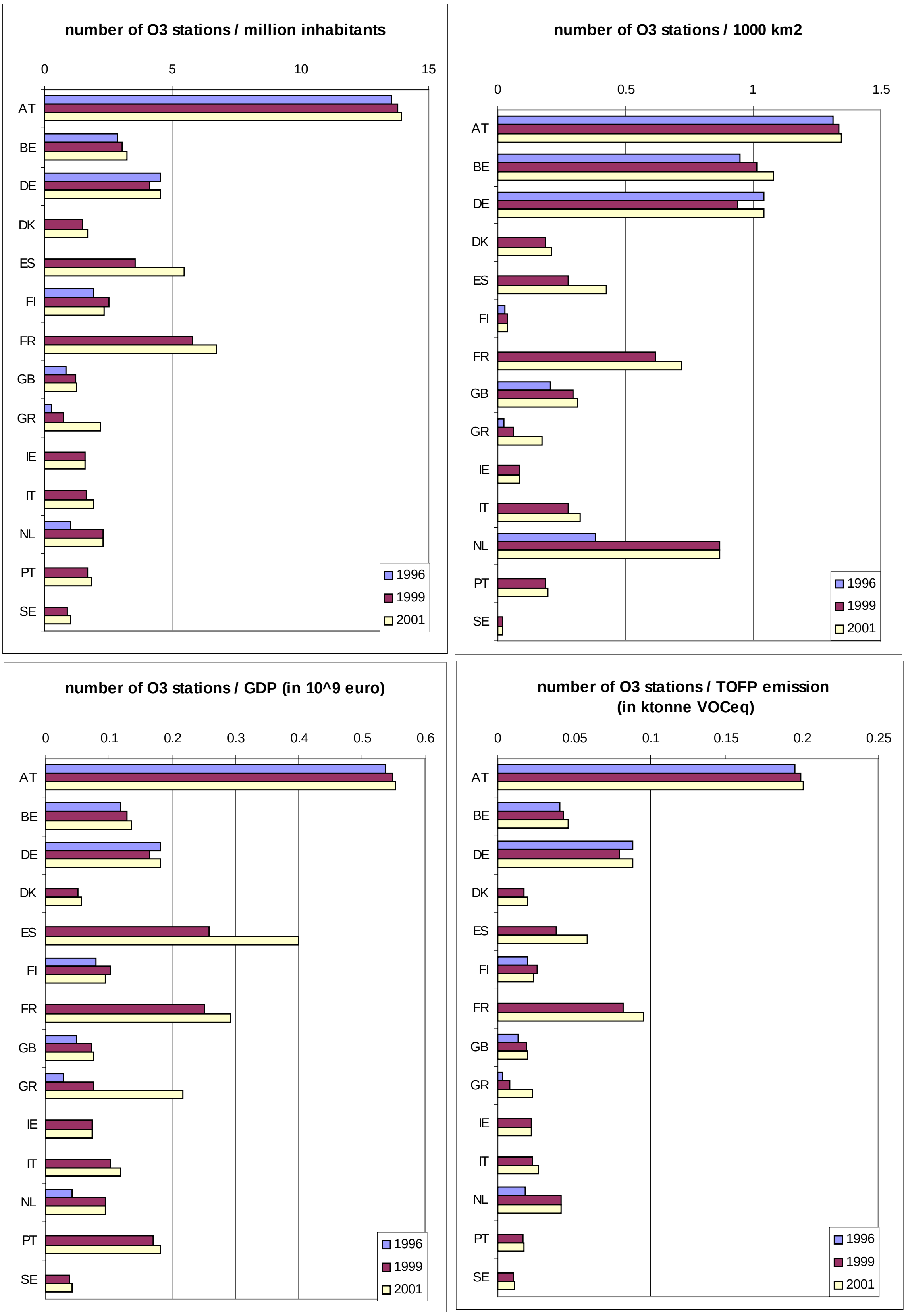


Figure 3. Density of ozone monitoring network expressed as number of stations per million inhabitants (top left); per 1000 km² (top right); per GDP (in 10^9 Euro, 1995 prices; bottom left) and per ktonne ozone precursor emissions (expressed in ktonne VOC equivalents).

The validity of the area as proxy for station density might be disputed. In the more remote areas with small gradients in concentration the stations may be representative for a wider area and a smaller density is expected. This is indeed seen in the Figures: lowest densities are given for Scandinavian countries. In the other parts of the EU the interpretation of the differences in density is less straightforward.

Presenting the station densities in terms of GDP or emissions does not result in a reduced variability. It might be argued that GDP is a too coarse as air quality should be related to the pollution level of the economical sector which have the largest contribution to the GDP. This might suggest using emission as proxy. When doing so, the ranking of the countries from high to low station density is changed but still a large variability is found. In this case one can state that, considering only national emissions, the importance of long-range transboundary air pollution is neglected.

In the daughter directives criteria for determining the minimum number of monitoring stations are given. The minimum number of sampling points to assess compliance with limit or target values for the protection of human health depends on the population size of the agglomeration or zone and on the ratio between actual concentration and upper assessment threshold. For ozone the required density ranges from 2 stations per million for small zones to 1.3 or less for zone/agglomeration with more than 3.75 million inhabitants. For the other pollutants the range is from 4 to about 1.5 stations per million if concentrations are above the upper assessment threshold. In case concentrations are below the upper assessment threshold, the range is 2 – 0.75 stations per million. Without detailed information on location, size and pollution levels it can not be judged whether the station density is in compliance with the criteria. Assuming an average population size of 2.5 M the required station density is in the range of 1 –2 station per million. This density is realised in most but not all of the Member States.

To assess compliance with limit or target values for the protection of ecosystems and vegetation the required density of NO_2 and SO_2 stations is 0.05 or 0.025 station per 1000 km^2 in case maximum concentration is above cq below the upper assessment threshold. For ozone a density of 0.02 station (0.04 in complex terrain) per 1000 km^2 is required. With some exceptions the required density is met.

The agreement (or differences) in station classification is shown by relating the number of urban stations to the urban population, the number of traffic stations is related to energy consumption by road traffic and the number of rural stations is related to the total area. (results for PM_{10} are given in Figure 4; similar figures for the other pollutants are given Annex B). Again no harmonised picture emerged. Variability between countries seems even to be larger than seen in the density graphs based on total number of stations.

5. CONCLUSION

The situation before and after implementation of the Framework directive and related daughter directive is analysed by comparing the situations in 1996, 1999 and 2001. In this period an increase in the number of station is seen but, in relative terms, there has been no changes from less rural background station in favour of more urban background stations. At the end of 2001, the monitoring networks for SO_2, NO_2 PM_{10} and lead must have been brought inline with the requirements from the 1st Daughter Directive. Compliance of the networks with the monitoring requirements in 2nd and 3rd Daughter Directive must be realised before end 2002 and 2003, respectively. A further adaptation of networks can not be excluded.

The density of the monitoring networks varies strongly over the Member States. The introduction of the Framework Directive seems not to result in a notable harmonisation of the air quality networks in EU Member States after 1999; this might well be related to the fact that the period 1999-2001 is too short for the reconstruction and/or adaptation of the monitoring networks.

The information available from AIRBASE indicates that the minimum station density in urban agglomerations and rural areas as required by the Framework Directive might not be realised in all countries.

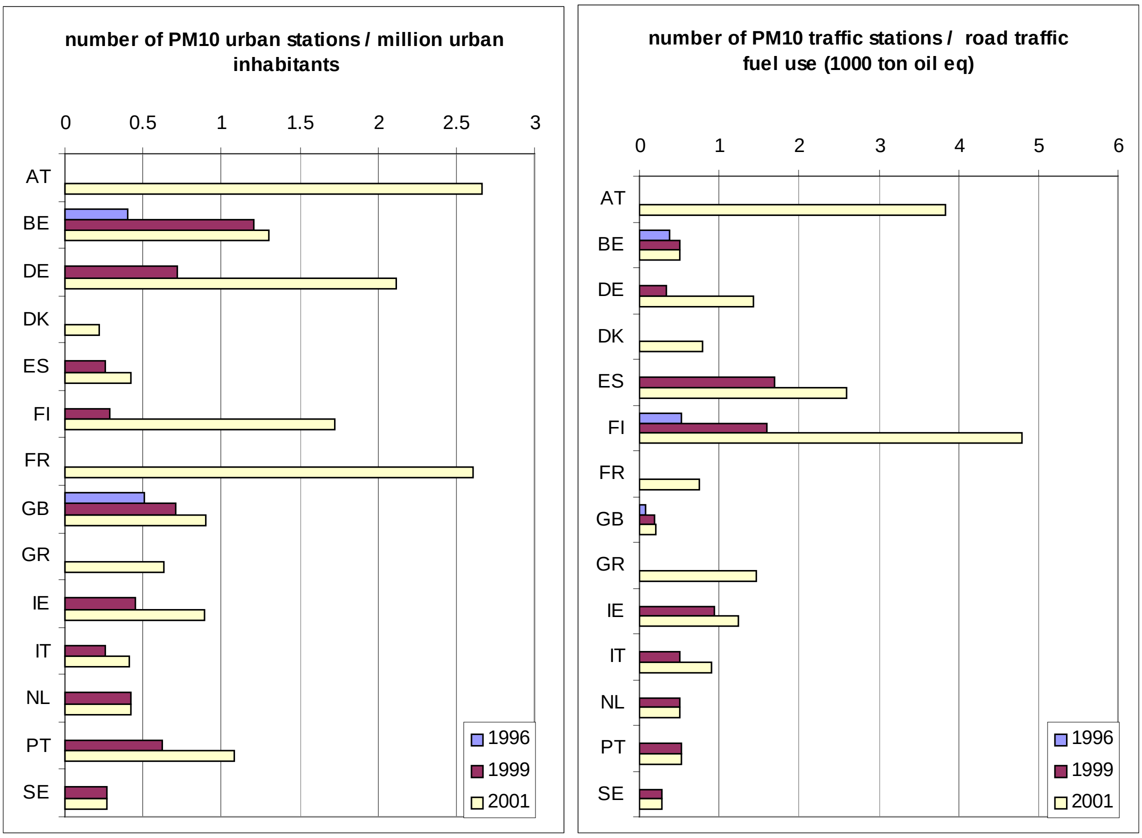


Figure 4. Density of PM10 monitoring stations; left: number of urban stations per million urban inhabitants; right: number of traffic stations per ktonne of fuel used in road traffic.

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ANNEX A

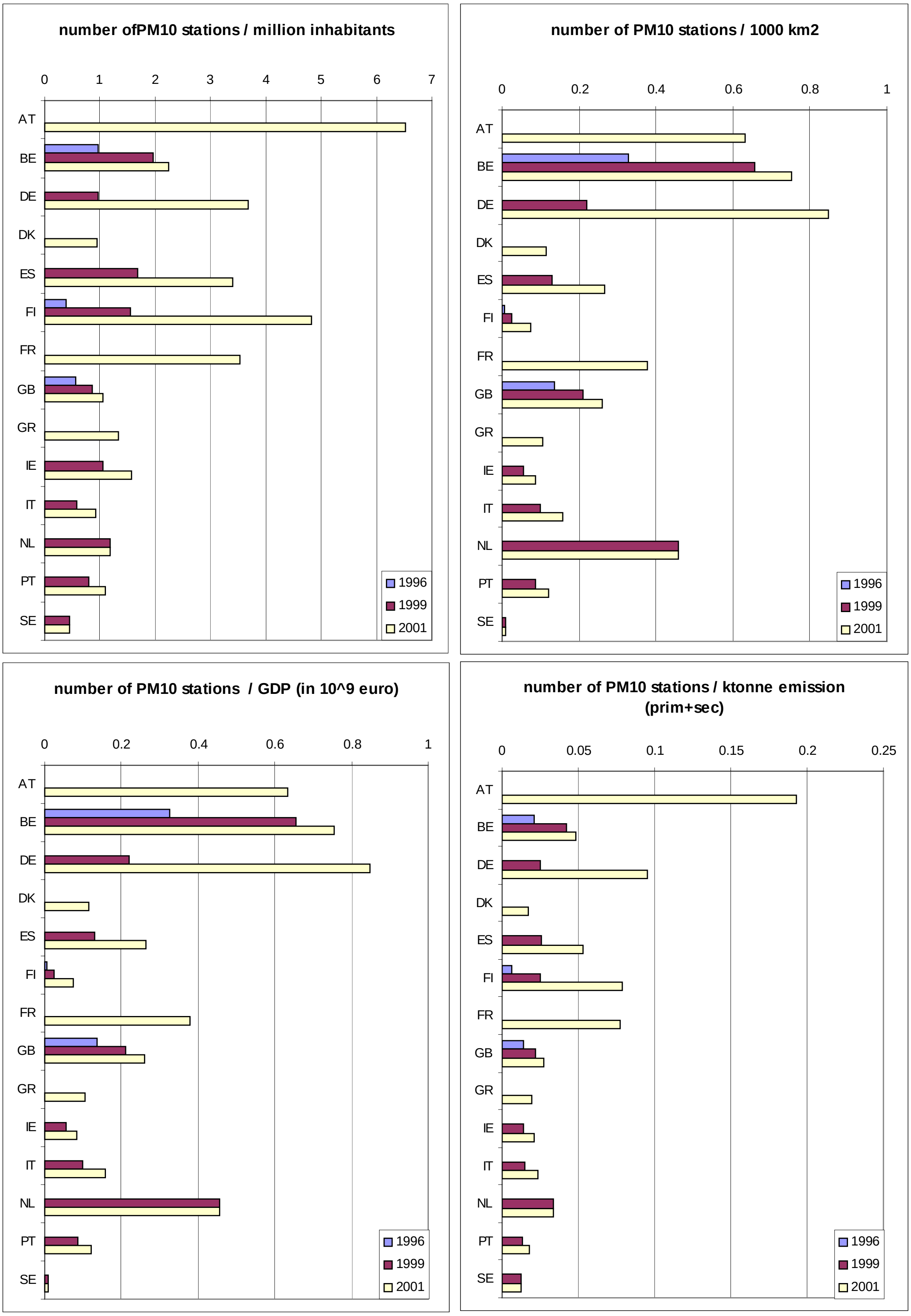


Figure A.1. Density of PM_{10} monitoring network expressed as number of stations per million inhabitants (top left); per 1000 km^2 (top right); per GDP (in 10^9 Euro, 1995 prices; bottom left) and per ktonne primary and secondary emissions (bottom right).

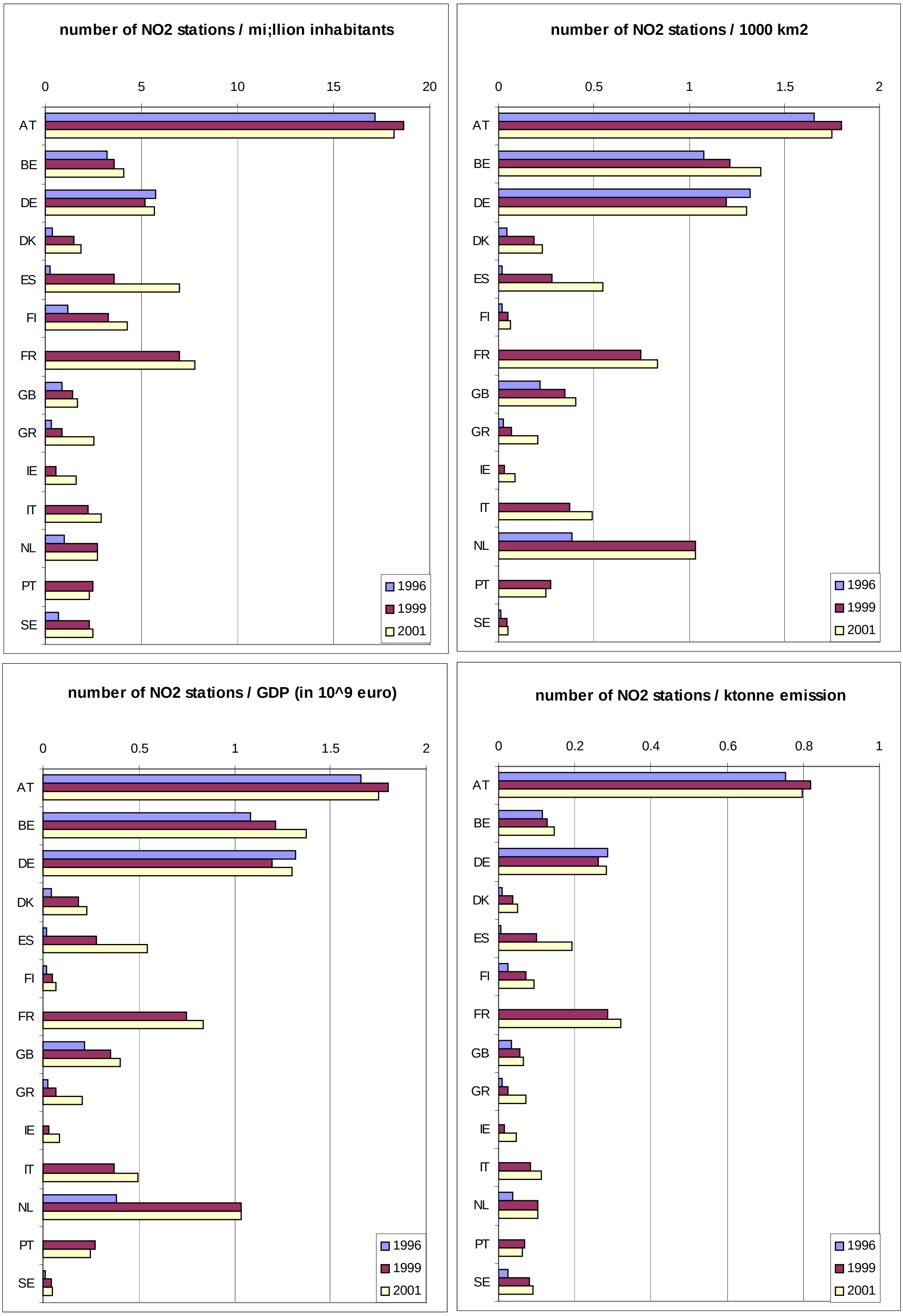


Figure A.2. Density of NO_2 monitoring network expressed as number of stations per million inhabitants (top left); per 1000 km^2 (top right); per GDP (in 10^9 Euro, 1995 prices; bottom left) and per ktonne emissions (bottom right).

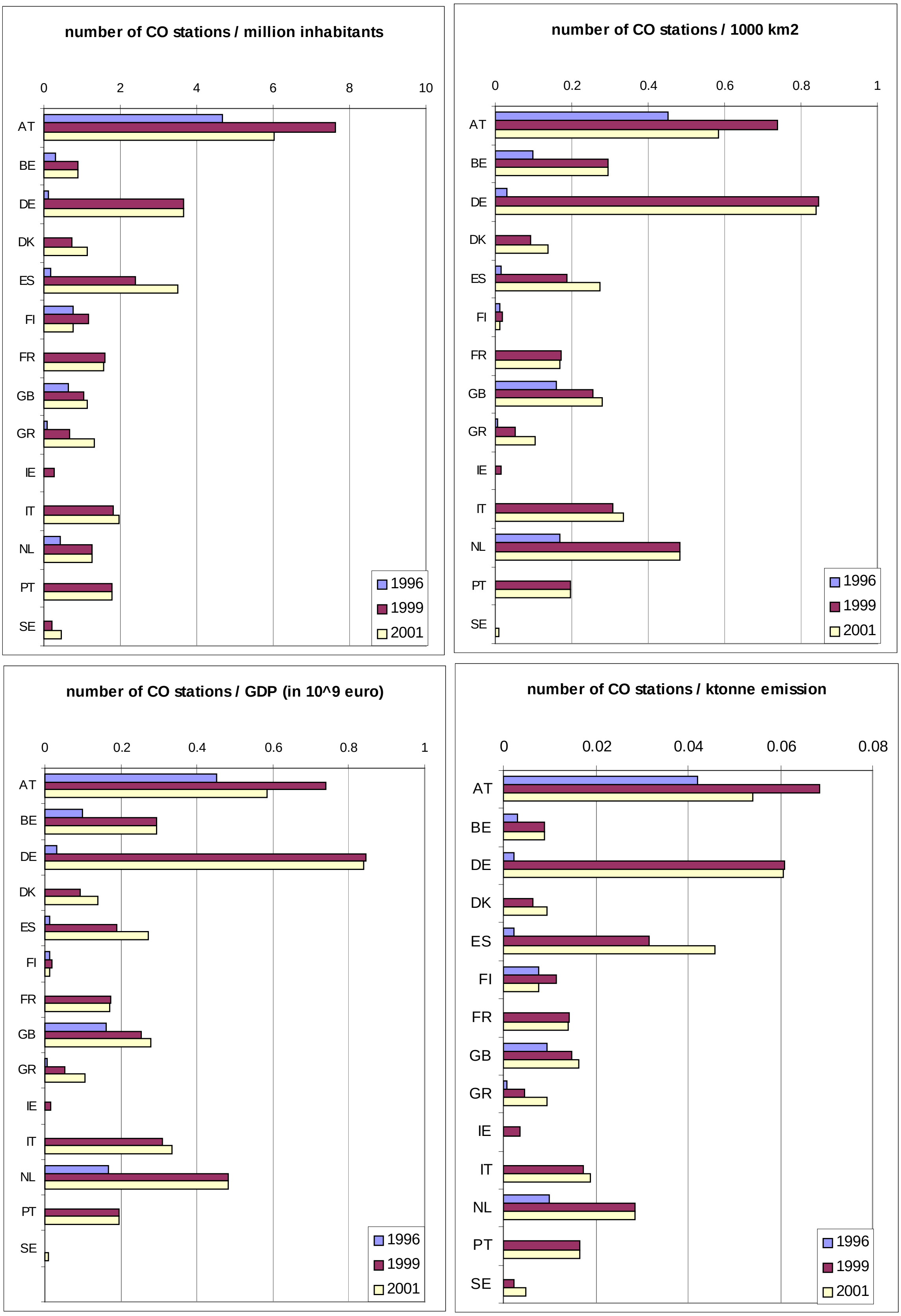


Figure A.3. Density of CO monitoring network expressed as number of stations per million inhabitants (top left); per 1000 km^2 (top right); per GDP (in 10^9 Euro, 1995 prices; bottom left) and per ktonne emissions (bottom right).

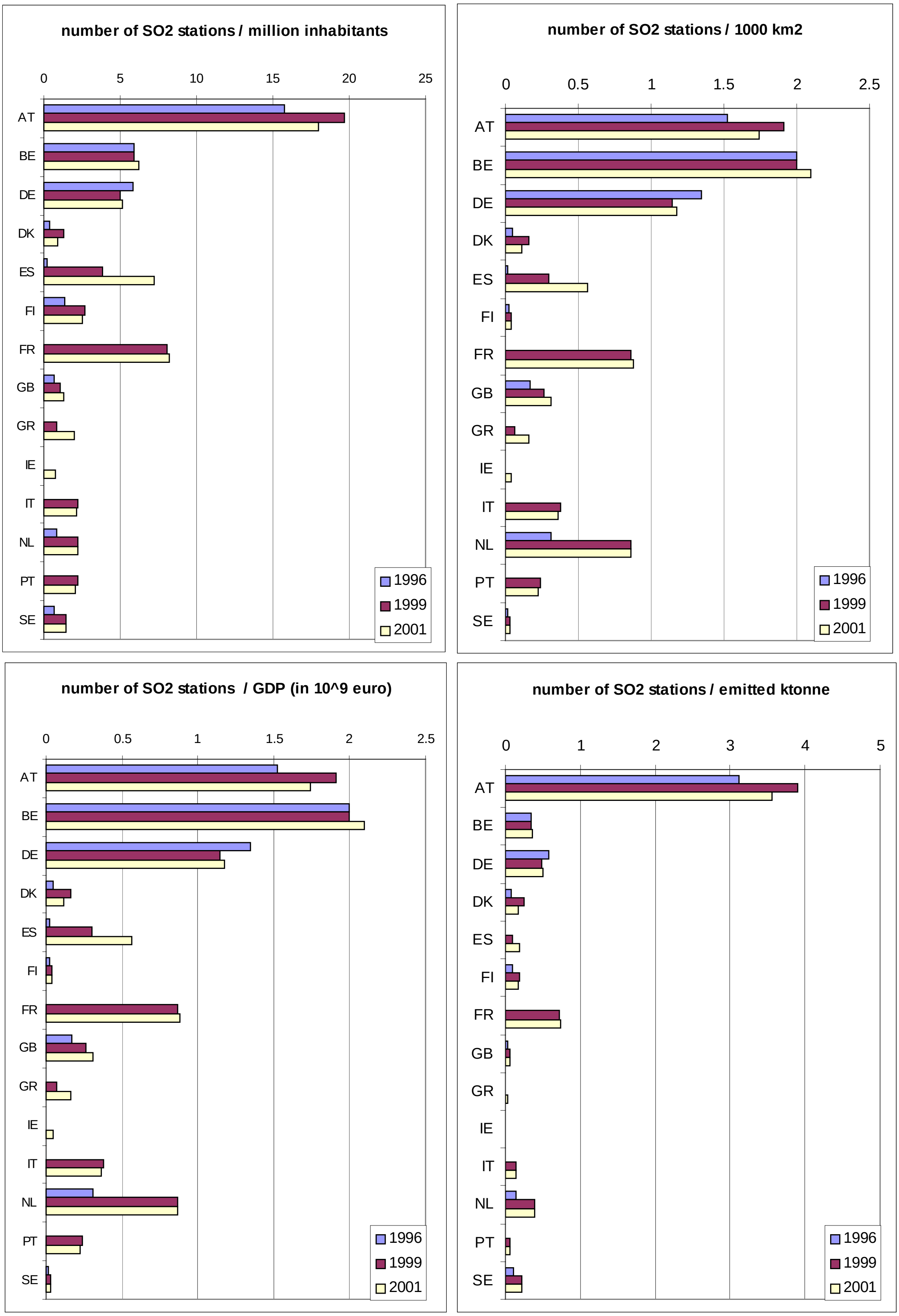
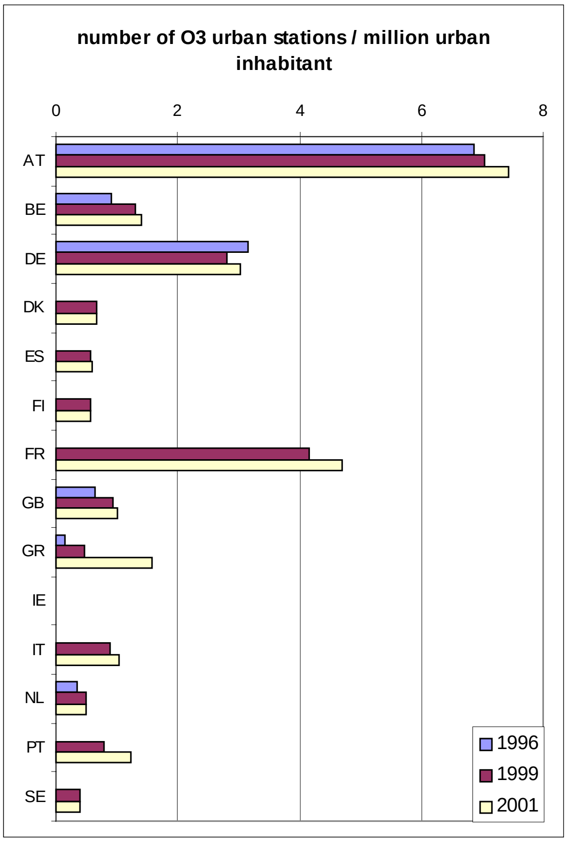
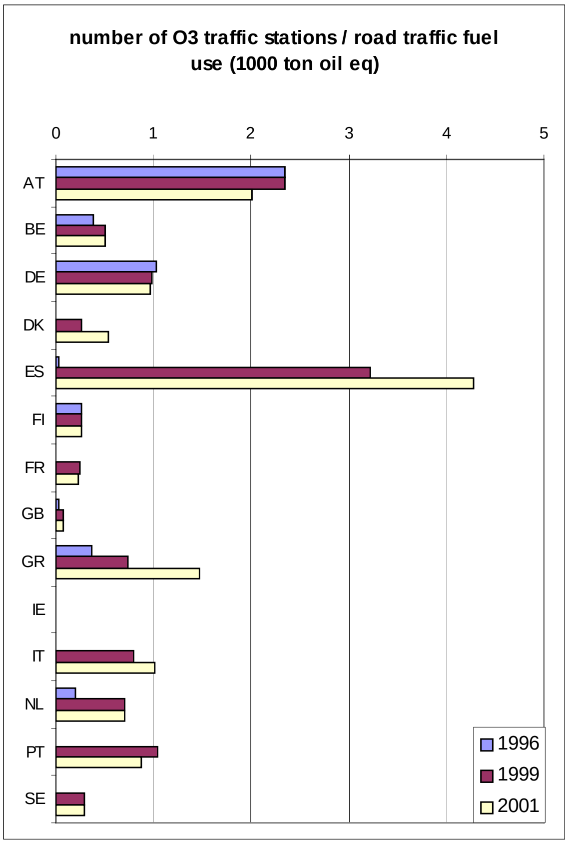


Figure A.4 . Density of SO_2 monitoring network expressed as number of stations per million inhabitants (top left); per 1000 km^2 (top right); per GDP (in 10^9 Euro, 1995 prices; bottom left) and per ktonne emission (bottom right).

ANNEX B





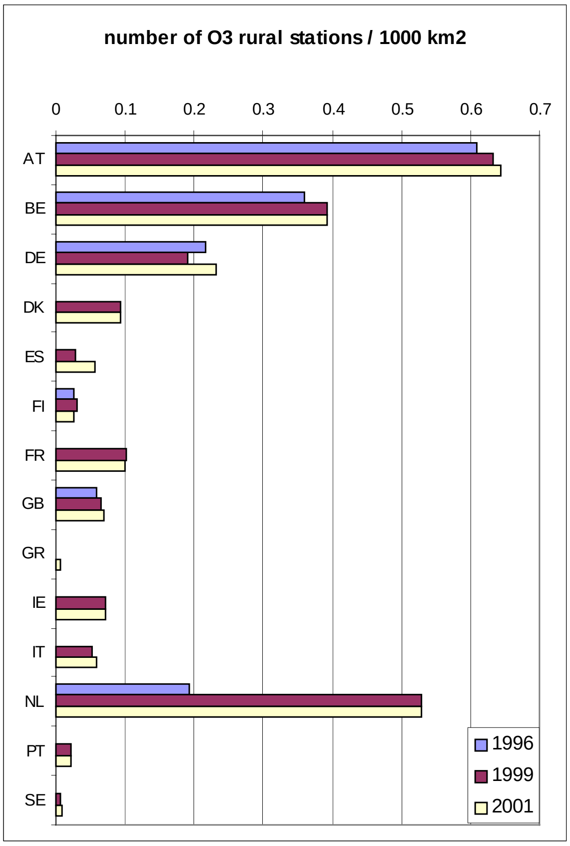
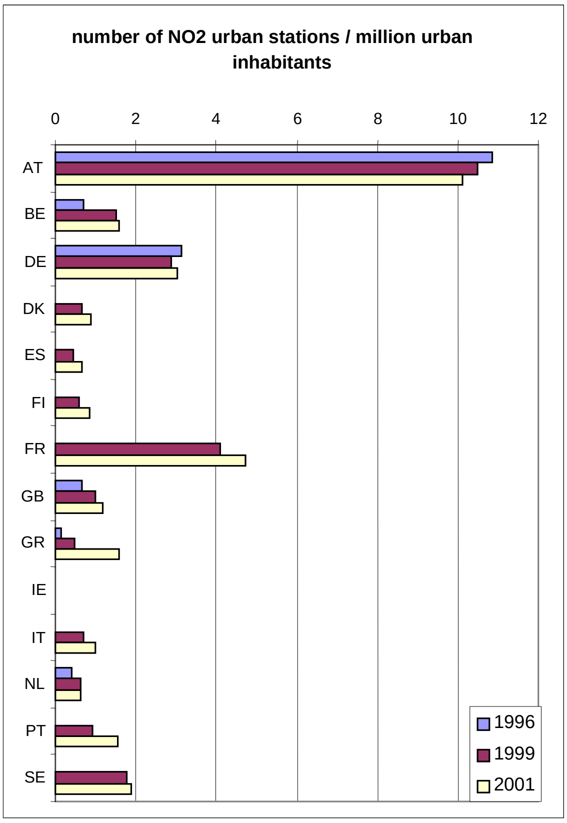
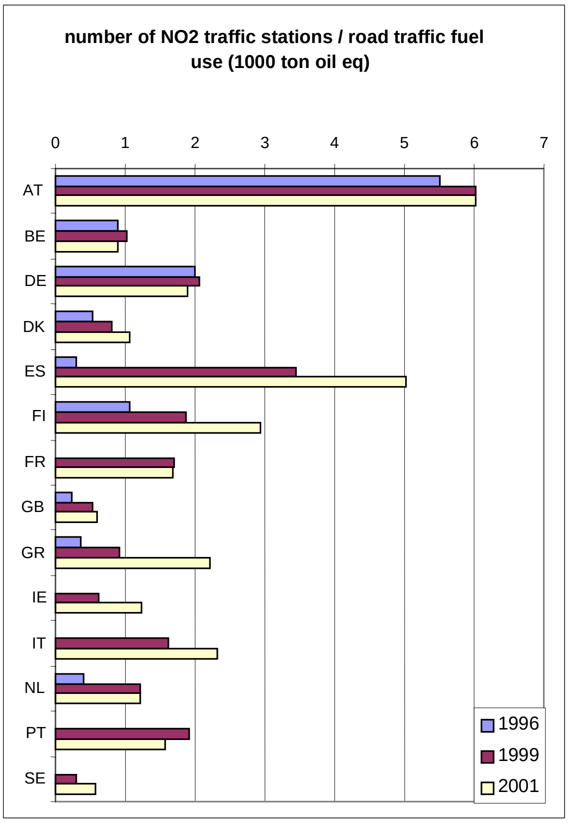


Figure B.1. Density of ozone monitoring stations; top left: number of urban stations per million urban inhabitants; top right: number of traffic station per ktonne of fuel used in road traffic; bottom: number of rural station per 1000 km².





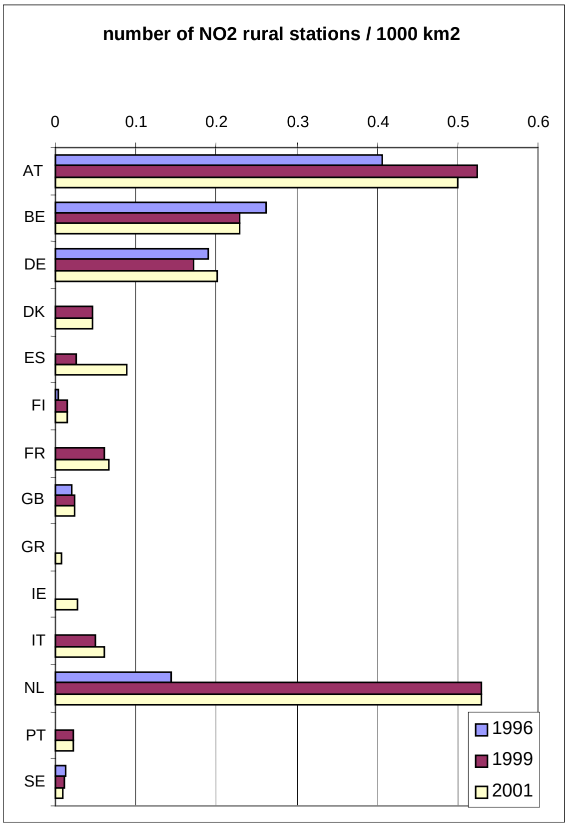


Figure B.2. Density of NO_2 monitoring stations; top left: number of urban stations per million urban inhabitants; top right: number of traffic stations per ktonne of fuel used in road traffic; bottom: number of rural station per 1000 km^2.

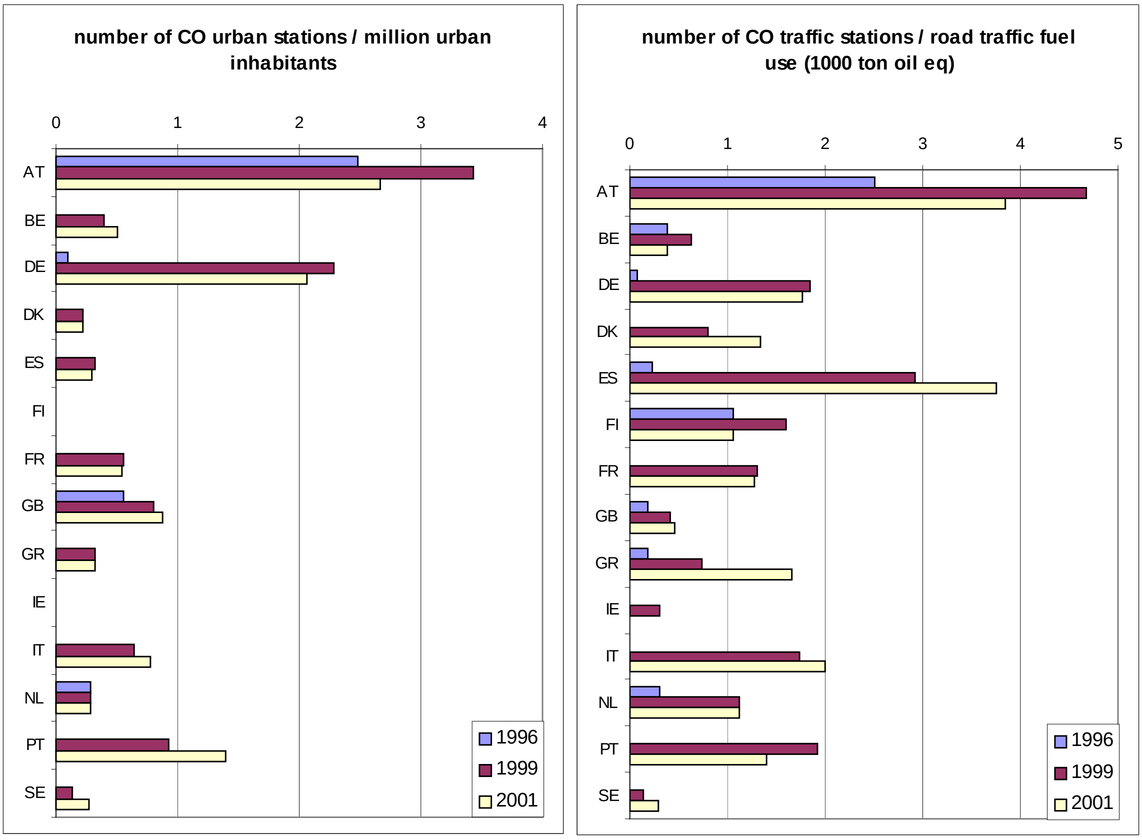
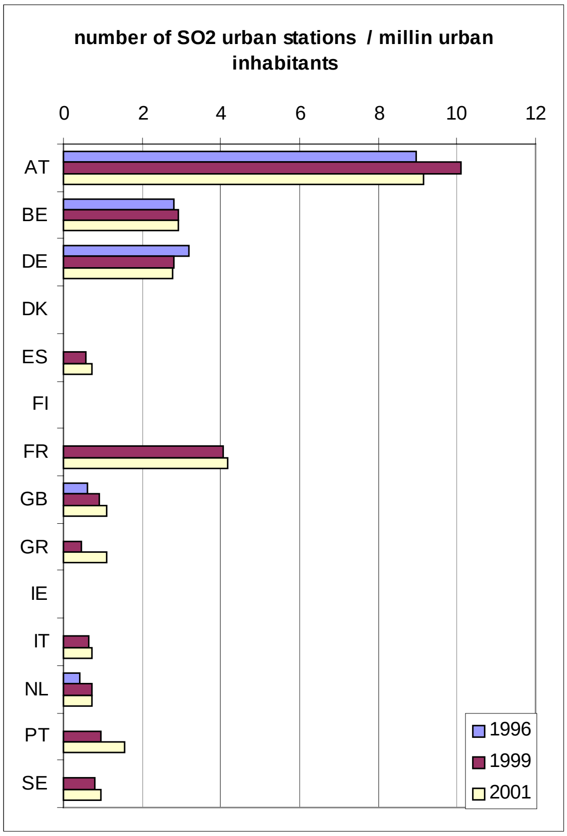
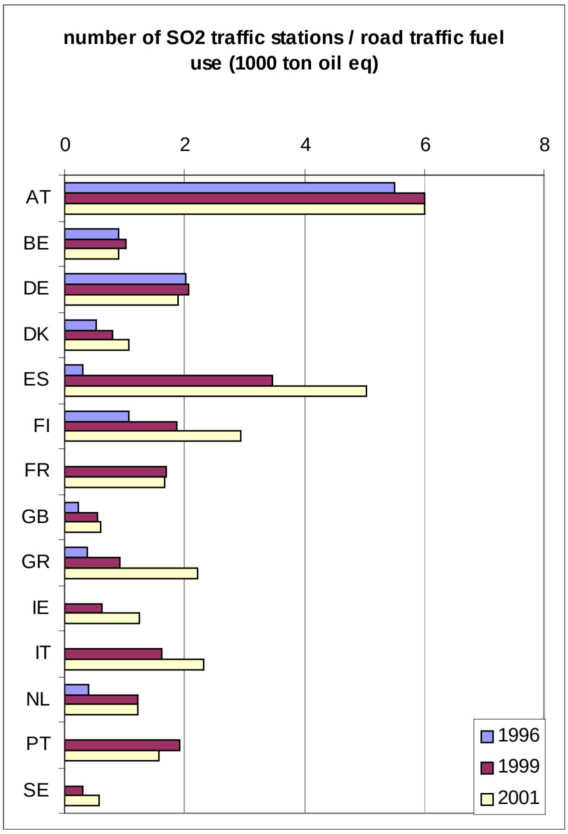


Figure B.3. Density of CO monitoring stations; left: number of urban stations per million urban inhabitants; right: number of traffic stations per ktonne of fuel used in road traffic.





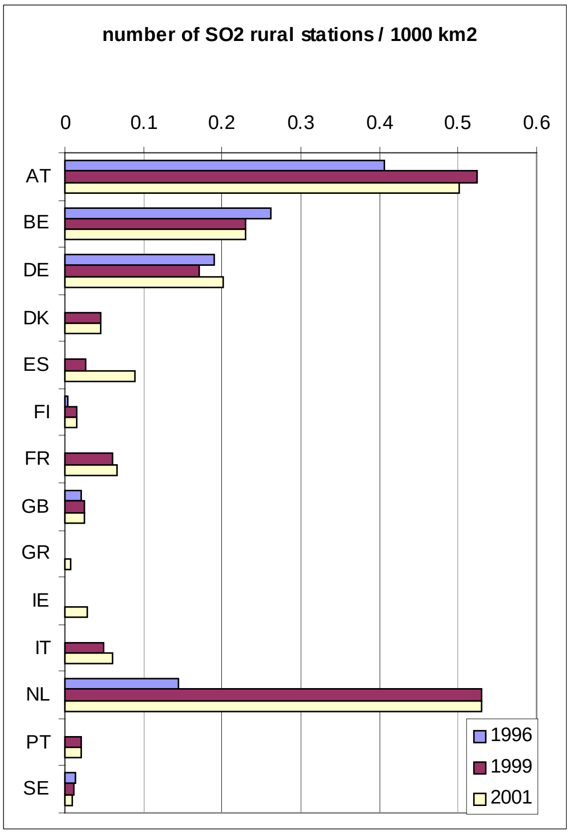


Figure B.4. Density of SO_2 monitoring stations; top left: number of urban stations per million urban inhabitants; top right: number of traffic stations per ktonne of fuel used in road traffic; bottom: number of rural stations per 1000 km^2