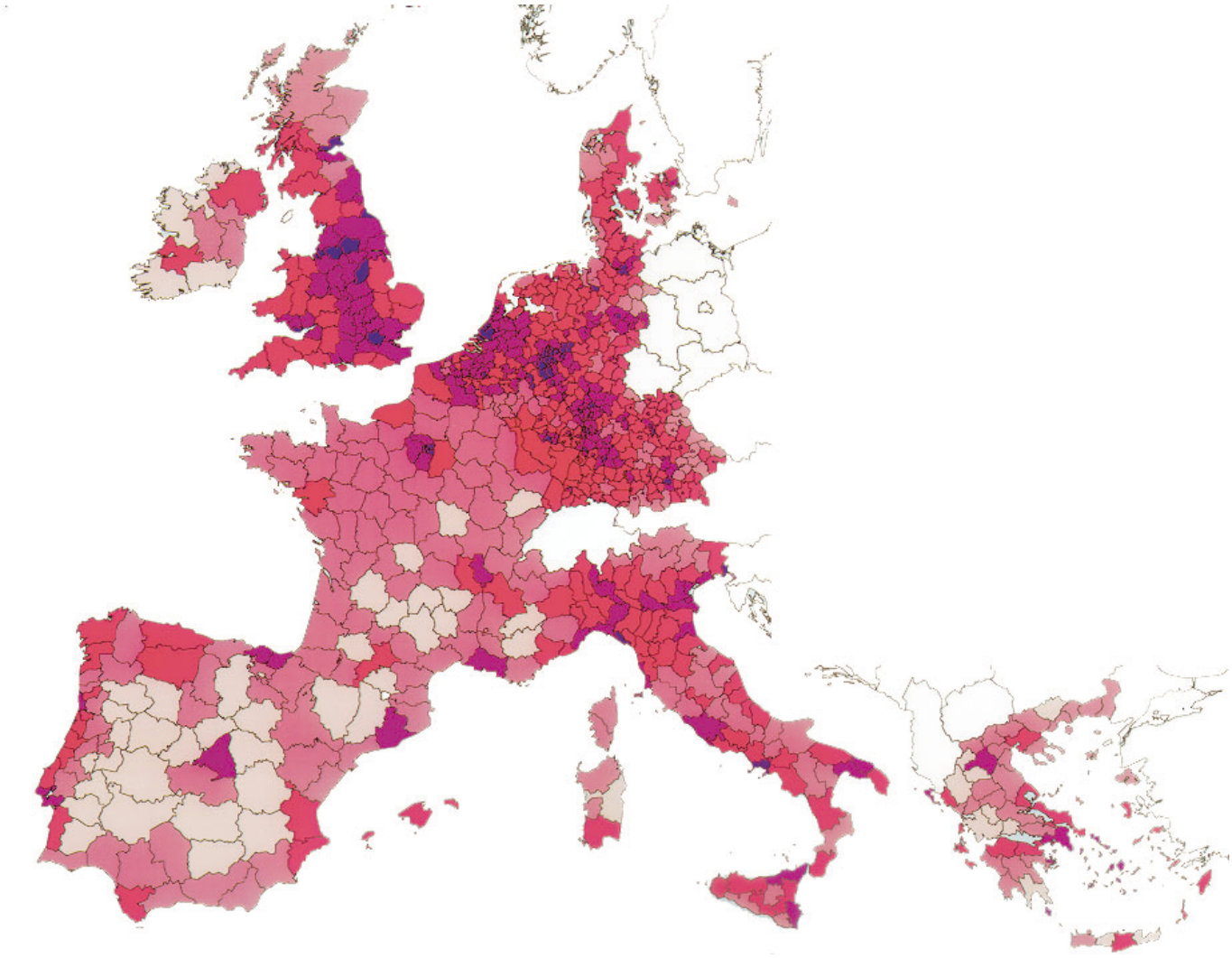
CORINAIR 90
Comprehensive Summary Report

Final Draft



March 1996

Report to the European Environment Agency from the European Topic Centre on Air Emissions

Table of contents

Preface

CORINAIR90 is an air emission inventory for Europe for 1990, initiated by the European Community as part of the CORINE (Coordination d'Information Environmentale) work programme. The CORINAIR system has now been integrated into the work programme of the European Environment Agency and the work is continuing through the Agency's European Topic Centre on Air Emissions.

In this report an overview is presented of the results of CORINAIR90, based on several summary reports which the EEA previously has made available.

Emissions are described and presented in different ways: for example by pollutant, by main process source, by geographical, by the contribution to environmental themes (climate change and acidification) and the contribution to economic sectors. The emissions per main sector and pollutant are also available via Internet (EEA WWW homepage).

The data reported here are not fully consistent with those reported in line with the IPCC Guidelines for National Greenhouse Gas Inventories under the UN Framework Climate Change Convention, or the EU Decision on a Monitoring Mechanism for CO_2 and other greenhouse gases. CORINAIR90 data has been used by several countries as a basis for such reporting but this requires careful re-allocation and re-aggregation between reporting categories, as highlighted in the IPCC Guidelines. Some gaps and inconsistencies will be resolved between IPCC and the EEA when future inventories are prepared.

It should also be noted that the data in CORINAIR90 are not fully consistent with those in CORINAIR85. For example the number of sources for non-methane volatile organic compounds has been increased and the emission factors for traffic nitrogen oxides are not consistent for the two databases. However on an aggregated level comparisons have been made between the data for 1985 and 1990.

The results of CORINAIR90 provide the most detailed, complete, consistent and transparent European atmospheric emission inventory to date. However the results are estimates of actual emissions with significant uncertainties in some cases. Furthermore some gaps and inconsistencies remain.

Comments and observations on the results presented in this report are welcome to assist in the longer term development of the methodology.

Summary

The CORINAIR90 process produced the most complete, consistent and transparent emission inventory for air pollutants for 29 countries (EU-12, EFTA-5, Phare-10 and Malta and Croatia). The inventory covers eight pollutants (sulphur dioxide, nitrogen oxides, non-methane volatile organic compounds, methane, carbon monoxide, carbon dioxide, nitrous oxide, ammonia) and around 270 emission generating activities. These activities are divided into eleven main source sectors. For locating the emission sources the geographical nomenclature of Eurostat has been used (NUTS or Nomenclature of Territorial Units for Statistics).

The data available within the pan-European database CORINAIR90 have been collected in close cooperation with national experts within each participating country. The willingness of the countries and their national experts to participate has made this first pan-European air emission inventory possible. The initiative on the inventory was taken by the European Environment Agency (EEA) Task Force within the European Commissions Environment Directorate General (DGXI) in 1991, in cooperation with the EMEP Task Force on Emission Inventories.

This task was taken over by the EEA (Copenhagen) in 1994 and work is continuing through its European Topic Centre on Air Emissions.

During the process of compiling the inventory much effort has been put into the screening of data from individual countries. Several studies were performed to verify and validate the collected data using cross country comparisons of emission factors and independent estimates of the data. The remaining gaps and inconsistencies were identified. These results will be used to improve the next national inventories and the pan-European CORINAIR inventories.

The first results have been published previously in several summary reports. The total emissions per main sector and pollutant are presented here.

The emission data were first analysed by making correlations with socio-economic and geographic data. High correlations were found for the emissions of several pollutants and parameters such as population size, number of cars, energy consumption and economic production. For example, the emissions of carbon dioxide, nitrogen oxides, carbon monoxide and volatile organic compounds show high correlations with population size. Such results suggest a high inter country comparability and consistency of the emission data. For several situations low correla-

Main sector split of European total emissions in Gg

Sector	SO_2	NO_x	NMVOC	NH_3	N_2O	CO_2	CO	CH_4
Public power, cogeneration and district heating plants	14,948	3,759	55	1	97	1,332,191	807	43
Commercial, institutional and residential combustion	3,046	754	989	2	45	849,638	9,947	619
Industrial combustion	6,968	2,439	154	1	54	1,140,655	8,200	92
Production processes	923	392	1,220	172	356	179,915	3,188	76
Extraction and distribution of fossil fuels	45	82	1,376	0	0	27,052	63	10,408
Solvent use	0	1	4,920	0	0	379	1	0
Road transport	718	7,846	6,766	13	30	695,499	38,919	200
Other mobile sources and machinery	565	2,310	677	0	6	138,734	2,223	25
Waste treatment and disposal	87	241	506	128	13	83,171	4,427	8,752
Agriculture	1	50	759	5,267	726	22,450	579	14,793
Nature	573	50	4,347	115	553	294,780	1,358	10,406
Total Europe	**27,874**	**17,923**	**21,770**	**5,701**	**1,880**	**4,764,463**	**69,712**	**45,415**

tions are obtained, e.g. between the emission of sulphur dioxide, population size and energy consumption. This can be partly explained by differences in fuels for the countries' energy supply and the level of technological development of the countries involved.

An analysis based on environmental burden was also performed. The environmental burden which is caused by air pollution can be considered in terms of "themes", as presented in the Fifth Environmental Action Programme of the European Union (5EAP). Air emissions are relevant for climate change ("greenhouse gases" or GHGs), ozone depletion, acidification, air quality (urban, local, regional) and forest degradation. The theme of air quality, especially summer smog (e.g. ozone), was not studied using CORINAIR90 data, mainly because the composition of the volatile organic compounds is not known in sufficient detail. Furthermore a higher time resolution is required. However such assessments will be carried out in the near future by the EEA in collaboration with its Topic Centres on Air Quality and Air Emissions.

This report concentrates on the emissions of GHGs (carbon dioxide, methane, nitrous oxide) and of pollutants causing acidification (sulphur dioxide, nitrogen oxides, ammonia). The report analyses the emissions of these pollutants for the main target sectors as specified in the 5EAP (industry, transport, energy and agriculture). The two other target sectors (tourism and households) are not analysed in further detail.

In general the CORINAIR90 data are very useful in describing the state of the environment using both "environmental themes" and the "target sector" approaches. For both themes stationary and mobile combustion processes are the most important contributors in all countries (70 to 80 %). The emission of GHGs is strongly related with energy demand and the use of fossil fuels. Differences between countries can partly be explained by the share of hydropower and nuclear power within the system for supply of electric energy. For acidifying pollutants, public power plants alone account for about 35 % of the total European emissions. Emissions of sulphur dioxide are an important part of these emissions, especially in Central and Eastern Europe. Ammonia from agriculture contributes about 20 % to the total acidifying emissions.

The emissions from several target sectors and emission sources within these target sectors have been analysed in more detail. For GHGs and acidifying compounds combustion is the major source within industry. Emissions from combustion plants within industry are mainly originating from small systems (less than 50 MW), whereas the emissions from public power plants are mainly resulting from large boilers (larger than 300 MW). For other pollutants within industry, production processes are the main source, for example the use of solvents for volatile organic compounds. Transport is an important source for carbon monoxide and nitrogen oxides, generating more than 50 % of the European total. For volatile organic compounds and carbon dioxide transport provides a smaller but still significant contribution to the European total (34 % and 18 %). Agriculture is an important sector for emissions of ammonia, contributing more than 90 % of the European total. About one third of the emissions of nitrous oxide also come from agriculture.

The European Topic Centre on Air Emissions is presently preparing to work with national experts on the compilation of an inventory for 1994. The number of pollutants will be increased by including heavy metals and persistent organic pollutants. Annual European emission inventories and future projections are also planned. This will greatly improve the relevance of CORINAIR in the policy making and assessment process.

1. Introduction

1.1 Background

In 1985 it was decided by the European Council of Ministers[1] to develop a work programme for co-ordination of the collection of information on the state of the environment: CORINE[2]. Within this work programme the European Commissions Environmental Directorate General (DG XI) initiated the compilation of the European Air Emission Inventory for the base year 1990 (CORINAIR90). The European Environment Agency (EEA) took over responsibility for CORINAIR in 1994 as part of the work program.

Countries participating in CORINAIR90:

- *European Union members* [3]:
  Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain and United Kingdom (EU-12)
- *EFTA countries[4]:*
  Austria, Finland, Norway, Sweden and Switzerland (EFTA-5)
- *Phare countries:*
  Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania Poland, Romania, Slovak Republic and Slovenia (Phare-10)
- Croatia and Malta

The aim of this activity is to compile a complete, consistent and transparent emissions database for all of the European territory. Apart from the member states of the European Environment Agency, countries from other parts of Europe are taking part in this activity as well. For Central and Eastern European countries financial support was provided by the European Commission via the Phare programme. The 29 participating countries are listed above.

1 Decision 85/338/EEC (Official Journal 1985)
2 Coordination d'INformational Environmentale
3 Memberships in 1990. The database still contains data on former West and East Germany, since the unification of Germany did occur by November 1990
4 Austria, Finland and Sweden joined the European Union in 1995

This report is based on the final databases for these countries except Croatia. Data for this country were not available in all details necessary for this report (only national main sector totals have been published). However, where relevant these data are given in the tables.
This report presents a comprehensive summary of the data available within the CORINAIR 1990 database. More detailed reports are available describing

- the national emissions of the 11 main source sectors [Ref. 1]
- the emissions within the 57 source subsectors [Ref. 2], and
- the emissions of large point sources. [Ref. 3].

1.2 Structure of the report

This report starts with a short description of the CORINAIR process and the systems used (chapter 2). The three relevant dimensions of the inventory (location, activity and pollutant) will be defined.
Chapters 3 through 5 will present results obtained in the CORINAIR90 process:

- The European totals per pollutant, split according to emission source (main sectors) and location (country) are presented in chapter 3.
- Chapter 4 concentrates on environmental burden and analyses the main causes of greenhouse gas emissions and acidification on the basis of the CORINAIR90 data.
- Chapter 5 analyses the emissions of a number of selected economic sectors.

This report ends with a chapter presenting the main conclusions and some remarks with respect to the collection and analyses of the next phase of work by the European Topic Centre on Air Emissions (ETC/AE, established by EEA), which will compile the emissions in Europe for the year 1994. The provisional results of this next inventory will be available by the end of 1996.

2. The CORINAIR emission inventory system

2.1 Database structure

Any inventory and hence also the CORINAIR inventory of EEA can be defined as a collection of data representing an emission (to air), each having a certain relevance along three independent dimensions:

- **chemical identity** of the pollutant,
- **activity** or technology,
- **location** of the emission (co-ordinates on a map and when relevant, source height).

A fourth dimension is time. Since CORINAIR, like most other inventories, chooses the year as its time base and stores annual totals, this fourth dimension is not further touched upon.

Different users of an inventory will in general ask for aggregations of the data in one or more of these dimensions. Such aggregations are possible with the CORINAIR database.

Chemical identity: pollutant

CORINAIR90 collected emission data on 8 pollutants, as listed in Table 1. The choice of these pollutants was based upon information needs with respect to three environmental problems:

- the problem of **acidification**. One of the environmental problems on a European scale is that of acidification of soils and surface waters. To address these, protocols under the convention on Long Range Transboundary Air Pollution (LRTAP) request countries amongst others to provide information annually on the emissions of acidifying pollutants (SO_2, NO_x). Within the EMEP activities that are performed under the LRTAP convention these emission data are used to calculate acid transport and deposition all over Europe.
- **Climate change** has become a major item in public awareness. International agreements have been set up that need information on the greenhouse gases CO_2, CH_4 and N_2O (greenhouse gases GHGs). In addition information is requested on aerosol and tropospheric ozone precursors CO, NO_x, NMVOC and SO_2.
- the problems of **tropospheric ozone** can only be studied and dealt with if emission data on its precursors are available. These precursors are non-methane volatile organic compounds (NMVOC), CO and NO_x. The description of the problem of tropospheric ozone needs additional data and a much higher time resolution than available within the CORINAIR inventory. Therefore this report will not present any analyses on this theme.

Table 1 Pollutants in CORINAIR 90 and weighting factors for aggregation towards environmental themes (from [Ref. 4 and Ref. 5].

Pollutant		Acidification[1] Aeq/Gg	Greenhouse[2] effect Ceq/Gg
Methane	CH_4	0	24.5
Carbon monoxide	CO	0	0
Carbon dioxide	CO_2	0	1
Nitrous oxide	N_2O	0	320
Ammonia	NH_3	0.0588	0
Non-methane volatile organic compounds	NMVOC	0	0
Nitrogen oxides	NO_x	0.0217	0
Sulphur dioxide	SO_2	0.0313	0

[1] Aeq: Acid equivalents: weight percentage of H^+ ions.
[2] Ceq: 100 year integration time horizon global warming potentials [Ref. 5]

Activities and technologies: SNAP

The CORINAIR system is mainly based upon technological descriptions of activities, defined in the so called SNAP[1]. SNAP consists of a hierarchical system, three levels deep, describing:

- SNAP (main) sectors (11),
- SNAP subsectors (57) and
- SNAP activities (277).

This comprehensive report will present results on a relatively high aggregated level. Table 2 lists the main sectors as used in the CORINAIR database. The table also indicates the relation with economic sectors as defined in the Fifth European Environmental Action Programme [Ref. 6]. Chapter 5 will analyse the emissions originating from these highly aggregated economic sectors and will describe a few activities at a higher level of detail.

Table 2 Main sectors in CORINAIR 90 and economic sectors as defined in the Fifth Environmental Action Programme (see [Ref. 6]).

Main SNAP sector	Definition	Economic sector
1	Public power, cogeneration and district heating plants	Energy
2	Commercial, institutional and residential combustion	Energy
3	Industrial combustion	Industry
4	Production processes	Industry
5	Extraction and distribution of fossil fuels	Several
6	Solvent use	Several
7	Road transport	Transport
8	Other mobile sources and machinery	Transport
9	Waste treatment and disposal	Several
10	Agriculture	Agriculture
11	Nature	

Spatial dimension: NUTS

Table 3 lists the participating countries and gives some geographic and economic details. The CORINAIR system uses the geographical definitions of the NUTS[2] levels as defined by Eurostat for Western Europe. The first level represents the whole area of each country. Chapter 3 mostly presents data at this level, but a number of maps have been included, presenting a more detailed view.

Table 3 Participating countries in CORINAIR 90 and some geographic and economic details. Sources: [Ref. 8], [Ref. 11].

	COUNTRY	Population (mln)[5]	Area (1000 km^2)	GNP (mln US$)	Nr. of cars (mln)	Electricity (GWhr)
EU-12	Germany (former West)	61.0	248.6	1,172,000	30.7	
	Italy	57.7	301.3	826,000	27.4	189.6
	United Kingdom	57.4	244.9	646,000	21.5	298.5
	France	56.7	551.5	940,000	23.6	394.3
	Spain	39.0	504.8	336,000	12.0	145.8
	Netherlands	15.0	37.3	232,000	5.5	3.7
	Greece	10.1	132.0	48,000	1.7	34.1
	Belgium	10.0	30.5	152,000	3.9	60.9
	Portugal	9.9	92.4	41,000	2.6	26.9
	Denmark	5.1	43.1	93,000	1.6	4.8
	Ireland	3.5	70.3	27,000	0.8	14.3
	Luxembourg	0.4	2.6	9,000	0.2	0.9
EFTA-5[3]	Sweden	8.6	450.0	170,000	3.6	137.0
	Austria	7.7	83.9	121,000	3.0	43.5
	Switzerland	6.7	41.3	188,000	3.0	51.0
	Finland	5.0	338.1	99,000	1.9	36.6
	Norway	4.2	323.9	86,000	1.6	108.8
	Malta	0.4	0.3	2,000	0.1	1.1
PHARE-10	Poland	38.2	312.7	284,000	5.3	1.4
	Romania	23.2	237.5	152,000	1.3	10.9
	Germany (former East)[4]	16.6	108.3	198,000	4.8	
	Hungary	10.6	93.0	26,000	1.9	27.5
	Czech Republic	10.3	78.9			50.1
	Bulgaria	9.0	110.9	65,000	1.3	39.7
	Slovakia	5.3	49.0			21.4
	Lithuania	3.7	65.3		0.5	25.3
	Latvia	2.7	64.6		0.3	4.5
	Slovenia	1.9	20.3		0.6	
	Estonia	1.6	45.2		0.2	0.0
	Croatia	4.7	56.5			
	European total	**486.2**	**4739.0**			

The countries listed as EU and EFTA members and Malta will be considered in this report together as Western European Countries". The other countries (Phare and Eastern Germany) will be considered together as "Central and Eastern European Countries". Data on emissions in Croatia are only available as SNAP main sector national totals. If these have been included in tables and graphs, this will be explicitly indicated.

[1] Selected Nomenclature of activities for Air Pollution
[2] Nomenclature of territorial units for statistics
[3] Austria, Finland and Sweden joined the European Union in 1995.
[4] Former Eastern Germany is not a Phare country. In this report, however, it is regarded as such and added to the group of Eastern European countries
[5] mln = million

2.2 Data collection

The data available within the CORINAIR database have been collected in a close co-operation with national experts within each participating country. The initiative to collect the CORINAIR 90 inventory was taken by the European Environment Agency Task Force within the European Commissions Environmental Directorate General (DG XI). This task was taken over by EEA in 1994. A Technical Unit was established to prepare this project in close co-operation with the EMEP Task Force on Emission Inventories. Within each of the participating countries a national expert was identified who was responsible for data collection within that country.

Within the CORINAIR framework a software system was developed to assist national experts in estimating emissions and storing them in a national database. In addition guidance was provided in the form of Default Emission Factors Handbook [Ref. 10]. The national databases were submitted to the project leader (CITEPA, Paris) and combined to the total European emission database.

The compilation of national databases into the European CORINAIR 90 emission database also comprises a screening procedure to detect and repair any inconsistencies. This screening has removed many errors and inconsistencies, thereby greatly increasing the comparability, consistency and transparency of the database. Although this screening was performed by the project leader, national experts remain fully responsible for the quality of the data.

The final and official CORINAIR 90 emission inventory is now stored at EEA and the ETC/AEM in a GIS system containing an Oracle database and an ARCINFO geographical information system.

2.3 Verification and validation

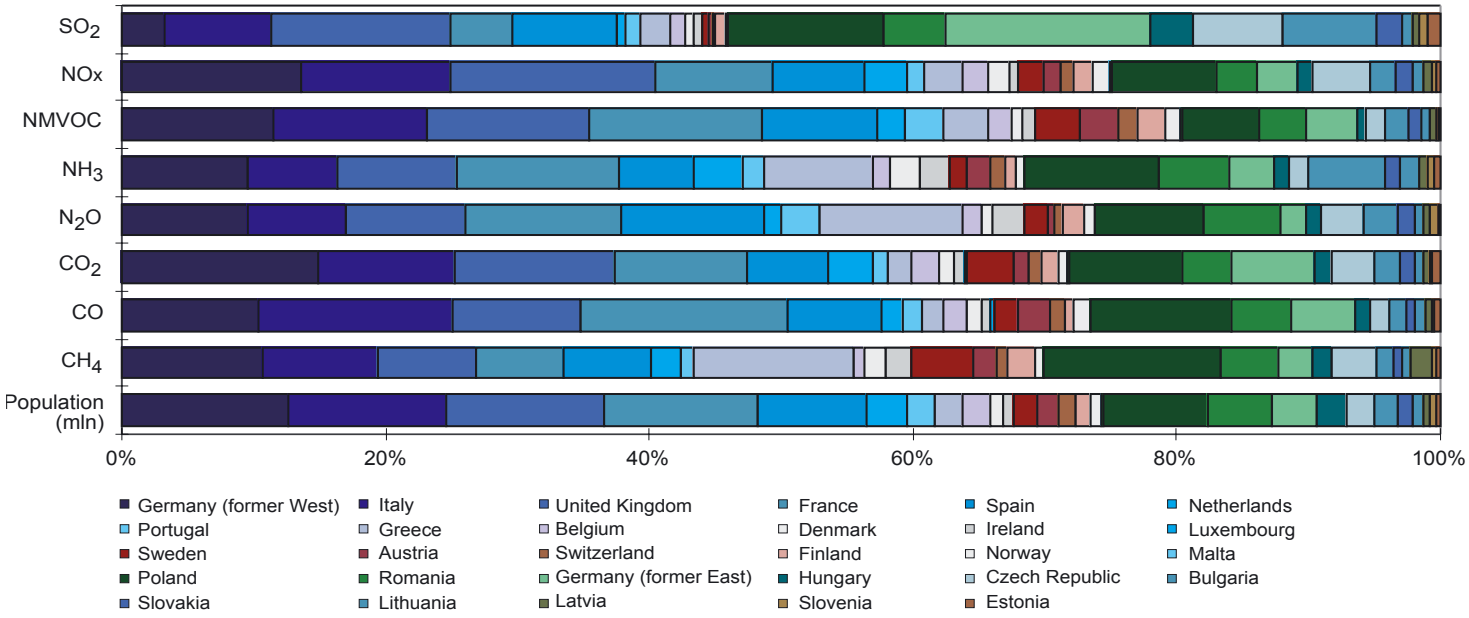
As indicated above, during the process of compiling the inventory much effort has been put into the screening of data delivered by individual countries. Apart from this efforts a number of studies were performed to verify and validate the collected data using cross country comparisons of emission factors and comparing with independent estimates of (part of) the data. The results of the various studies are used to improve the next national inventories and the European CORINAIR Inventory (e.g. CORINAIR 94). Methods for emission inventories are described in [Ref. 15].

3. Emissions to the air in Europe

3.1 National totals

This section presents national total emissions, including anthropogenic and biogenic emissions, as stored in the CORINAIR90 inventory (Figure 1 and Table 4). For a comparison the size of the population in each country is also given. As can be seen different countries make different contributions to the European total emissions. For all pollutants, except SO_2, the distribution of emissions over the countries is very similar to the distribution of the population: in most cases larger countries make larger contributions to these totals.

Figure 1 Contribution of national totals to European emissions in 1990 (%). For comparison also the distribution of population over the countries is shown.



For SO_2 relatively high emissions occur in Eastern Europe as compared to the emissions of other pollutants and to the distribution of the population. The highest emissions of SO_2 occur in the former Eastern Germany. Second and third highest contributions originate from the United Kingdom and Poland.

Figure 2 shows the relations between the size of the population of each country and the emissions of the 8 CORINAIR pollutants. For each pollutant a regression analysis has been performed. The (linear) regression lines are forced through the origin of each graph. Because of the broad range of both the sizes of populations and the emissions to the air, all graphs are presented on logarithmic scales. The quality of the regression is indicated by giving the covariance (R^2) for each regression line. The following conclusions can be drawn:

- Very high correlations (R^2>0.9) are obtained for NMVOCs, CO_2, NO_x and CO. The size of the population explains more than 90 % of the between country variance of the emissions of these pollutants.

- per capita NMVOC emissions in Eastern Europe appear to be significantly below those in Western Europe. From the regression lines averages of 37 and 46 kg/cap are obtained respectively (not shown).
- A rather low correlation is observed for SO_2. In this case Eastern European countries show clearly higher SO_2 emissions per capita (105 kg/cap) compared to the Western European countries (37 kg/cap).
- For the other three pollutants (N_2O, CH_4 and NH_3) no clear differences between the two parts of Europe are directly visible. The lower correlations (R^2 between 0.5 and 0.7) might be due to real differences between countries or to uncertainties and inaccuracies in the methodology.

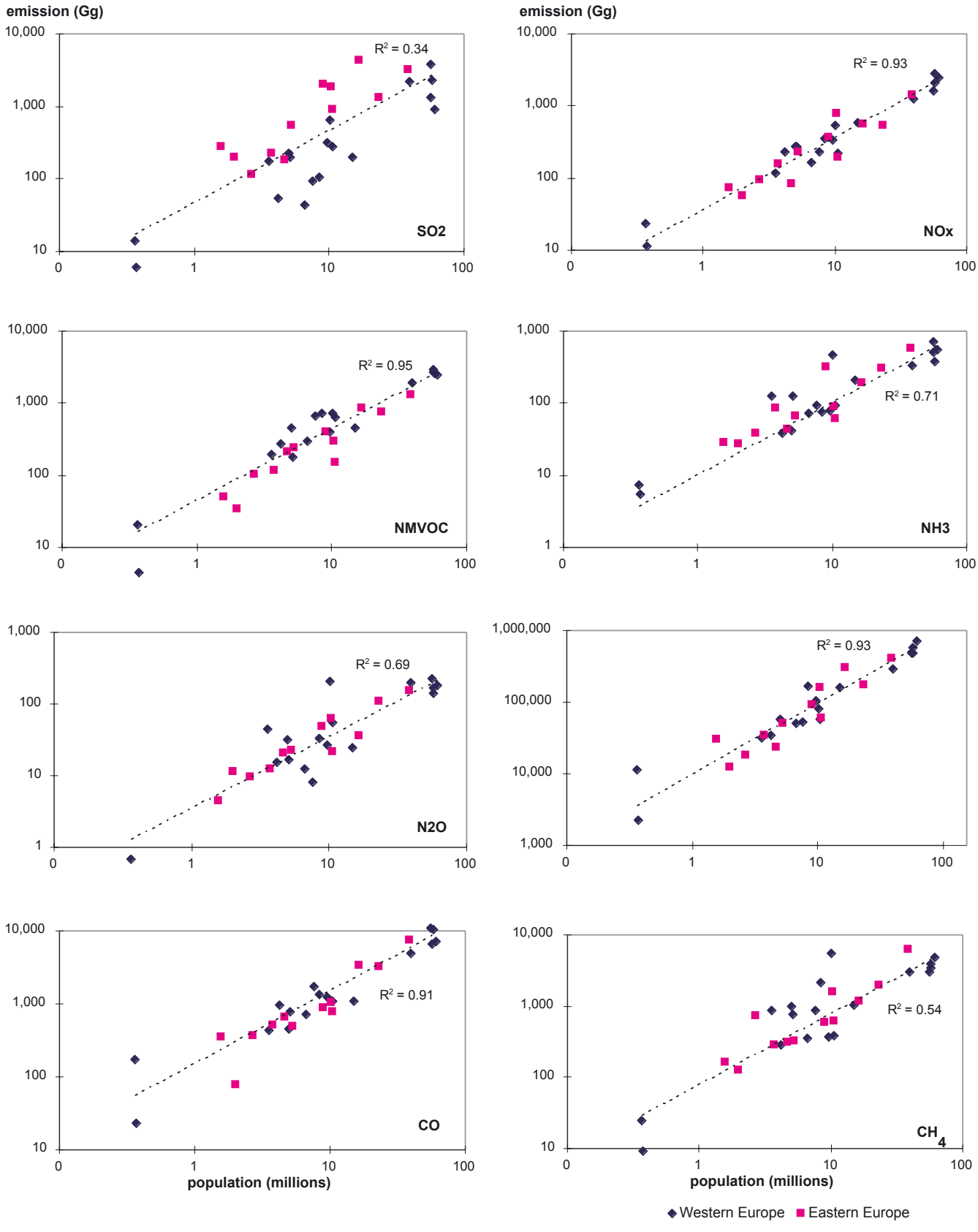
Table 4 National total emissions in 1990 (Gg). For comparison for each country the size of the population is given.

COUNTRY	SO_2	NO_x	NMVOC	NH_3	N_2O	CO_2	CO	CH_4	Population (mln)
Germany (former West)	912	2,424	2,484	546	178	708,093	7,181	4,884	61.0
Italy	2,253	2,053	2,548	383	142	492,038	10,347	3,928	57.7
United Kingdom	3,787	2,773	2,682	516	170	580,455	6,701	3,389	57.1
France	1,300	1,590	2,866	700	223	481,733	10,930	3,038	56.2
Spain	2,206	1,257	1,894	331	202	289,798	4,977	2,998	39.6
Netherlands	201	576	460	204	25	159,300	1,106	1,040	14.9
Portugal	283	221	644	93	55	57,402	1,086	391	10.5
Greece	641	544	718	471	205	81,804	1,143	5,508	10.1
Belgium	317	343	394	79	26	103,389	1,221	370	9.6
Denmark	198	273	178	126	16	56,031	789	761	5.1
Ireland	178	116	197	126	45	31,645	431	850	3.6
Luxembourg	14	23	20	7	1	11,244	171	25	0.4
Sweden	105	345	722	74	33	170,397	1,347	2,106	8.4
Austria	93	227	656	94	8	52,799	1,692	855	7.6
Switzerland	44	164	298	71	12	50,176	706	350	6.7
Finland	227	269	457	41	32	57,033	453	990	5.0
Norway	54	232	270	38	16	34,435	950	282	4.2
Malta	6	12	4	5	0	2,208	23	9	0.4
Poland	3,273	1,446	1,295	581	155	414,919	7,389	6,107	38.4
Romania	1,311	546	769	300	108	171,110	3,188	1,955	23.3
Germany (former East)	4,345	556	839	193	36	303,110	3,351	1,183	16.6
Hungary	905	191	148	62	22	60,841	768	611	10.5
Czech Republic	1,863	773	294	91	62	157,528	1,044	1,552	10.3
Bulgaria	2,008	361	394	324	48	91,055	901	589	9.0
Slovakia	542	227	237	66	22	50,630	501	323	5.3
Lithuania	222	158	116	84	12	34,507	521	286	3.8
Latvia	115	93	101	38	9	18,447	370	743	2.7
Slovenia	196	57	35	27	11	12,620	77	124	2.0
Estonia	275	72	50	29	4	29,716	347	165	1.6
European total	**27,874**	**17,923**	**21,770**	**5,701**	**1,880**	**4,764,463**	**69,712**	**45,415**	**481.3**
Croatia	180	83	210	44	21	23,807	651	313	4.7

[1] The CO_2 emission for former Eastern Germany in [Ref. 1] was rounded. This table presents the final value.

[2] Emissions in Croatia are not available in the detailed database and hence not included in the European total in this and subsequent tables.

Figure 2 Population dependence of the emissions in 1990. Linear regression lines and covariances (R^2) are also given.



3.2 Emissions per main sector

This chapter concentrates on the analyses of emissions by activity. As has been indicated above, CORINAIR stores emissions of the 8 pollutants according to a three level technology split (SNAP). Table 5 presents European total emissions per main sector and Table 6 and Figure 3 give the same information as percentages.

Table 5 Main sector split of European total emissions in 1990 (Gg).

Sector	SO_2	NO_x	NMVOC	NH_3	N_2O	CO_2	CO	CH_4
Public power, cogeneration and district heating plants	14,948	3,759	55	1	97	1,332,191	807	43
Commercial, institutional and residential combustion	3,046	754	989	2	45	849,638	9,947	619
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Production processes	923	392	1,220	172	356	179,915	3,188	76
Extraction and distribution of fossil fuels	45	82	1,376	0	0	27,052	63	10,408
Solvent use	0	1	4,920	0	0	379	1	0
Road transport	718	7,846	6,766	13	30	695,499	38,919	200
Other mobile sources and machinery	565	2,310	677	0	6	138,734	2,223	25
Waste treatment and disposal	87	241	506	128	13	83,171	4,427	8,752
Agriculture	1	50	759	5,267	726	22,450	579	14,793
Nature	573	50	4,347	115	553	294,780	1,358	10,406
Total Europe	**27,874**	**17,923**	**21,770**	**5,701**	**1,880**	**4,764,463**	**69,712**	**45,415**

Figure 3 Main sector split of European totals (%).

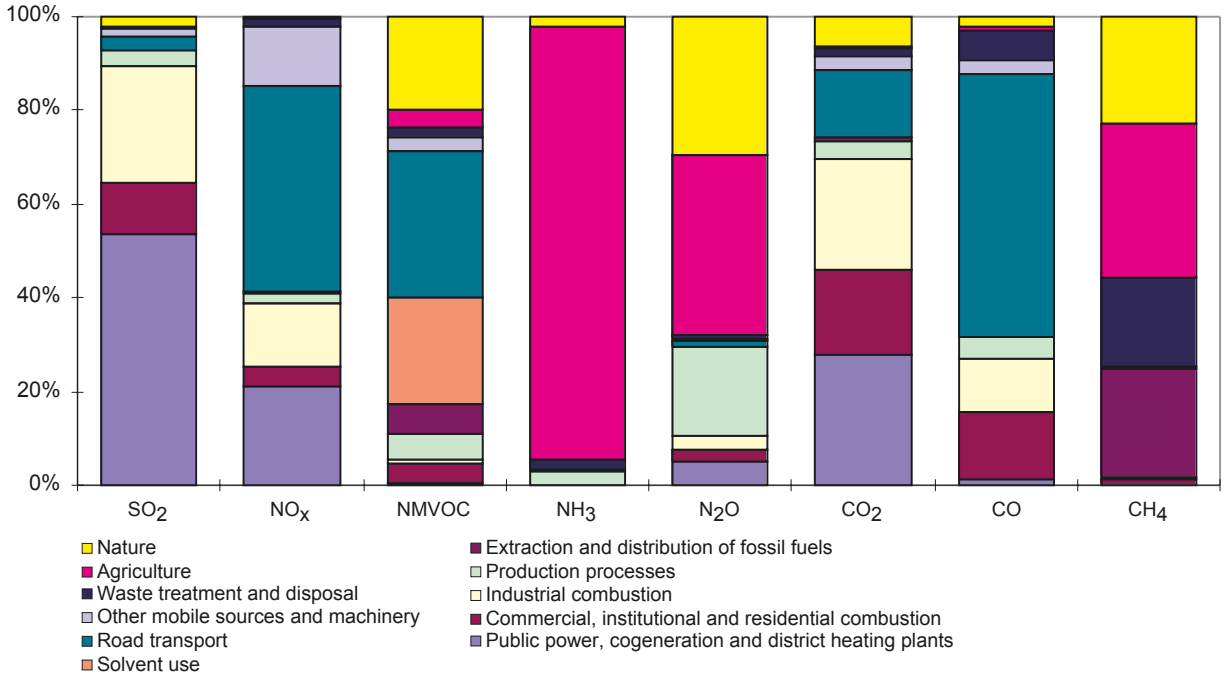


Table 6 Main sector split of European total emissions in 1990 (%).

Sector	SO_2	NO_x	NMVOC	NH_3	N_2O	CO_2	CO	CH_4
Public power, cogeneration and district heating plants	54	21	0	0	5	28	1	0
Commercial, institutional and residential combustion	11	4	5	0	2	18	14	1
Industrial combustion	25	14	1	0	3	24	12	0
Production processes	3	2	6	3	19	4	5	0
Extraction and distribution of fossil fuels	0	0	6	0	0	1	0	23
Solvent use	0	0	23	0	0	0	0	0
Road transport	3	44	31	0	2	15	56	0
Other mobile sources and machinery	2	13	3	0	0	3	3	0
Waste treatment and disposal	0	1	2	2	1	2	6	19
Agriculture	0	0	3	92	39	0	1	33
Nature	2	0	20	2	29	6	2	23

The following conclusions are drawn:

- **Public power, cogeneration and district heating plants** is the major source sector of SO_2 emissions in Europe. This sector contributes over 50% to the total emissions. An important fraction of the emissions of CO_2 and NO_x is also due to this main sector.
- **Commercial, institutional and residential combustion** contributes nearly 20% to the total emissions of CO_2 and nearly 15% to emissions of CO.
- **Industrial combustion** is the second largest source of SO_2 emissions. About one quarter of the European total is due to this sector. A comparable part of the CO_2 emissions is also originating from this main sector.
- **Production processes** (as a main sector) contribute significantly only to N_2O emissions.
- **Extraction and distribution** of fossil fuels contributes only marginally to the emissions of all components except CH_4.
- **Solvent use** is an important main sector with respect to the emissions of NMVOC's.
- **Road transport** causes nearly 60% of all CO emissions in Europe. In addition it is the most important source of NO_x and NMVOC emissions, contributing about 45% and 30% to the European totals respectively.
- The largest contribution by **Other mobile sources and machinery** occurs for NO_x emissions (about 10%).
- **Waste treatment and disposal** causes about 20% of all CH_4 emissions.
- **Agriculture** is the dominant source of NH_3 emissions in Europe. Over 90% of all emissions is due to this sector. Agriculture also contributes significantly to the emissions of N_2O and CH_4 (40 and 30% respectively).
- **Nature** finally is an important source for NMVOC's, N_2O and CH_4.

Sulphur dioxide

As has been shown in section 3.1 the emissions of SO_2 in central and eastern European countries are relatively high, as compared to Western European countries. Figure 4 presents the main sector splits of SO_2 emissions for both groups of countries. It is shown that over 95% of the SO_2 emissions in Eastern Europe are due to stationary combustion processes. In Western Europe this activities contribute about 80% to the total emissions. The largest difference between both groups of countries appears in the emissions from combustion processes in commercial, institutional and residential applications.

3.3 Changes since 1985

CORINAIR 85 collected emissions of SO_2, NO_x and VOC in the former 12 European Union member states for the year 1985 [Ref. 13]. Due to the differences in methodology comparison is only possible to a certain extend for SO_2 and NO_x. Figure 5 compares the national totals for these components as stored in CORINAIR 85 and CORINAIR 90. The following is observed:

- All countries, except the former Western Germany, report a higher or equal NO_x emission in 1990 than in 1985.
- The introduction of flue gas desulphurization in the former Western Germany is reflected in a remarkable decrease of SO_2 emissions.

Changes in the other countries are less clear. Some of the other countries report increases, others decreases of SO_2 emissions.

Figure 4 Main sector split of SO_2 emissions in Western and Eastern European countries (%).

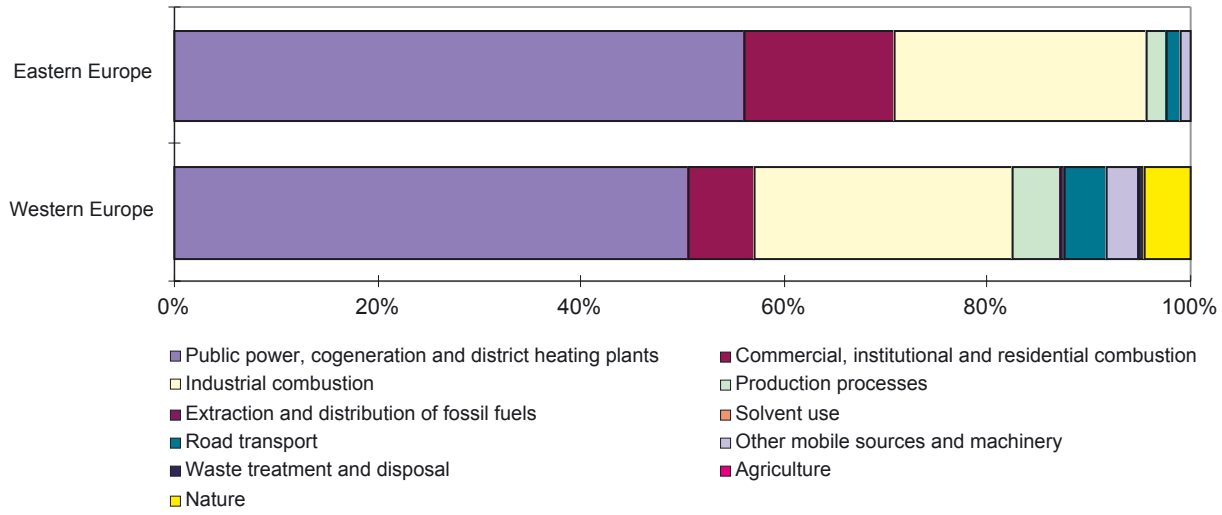
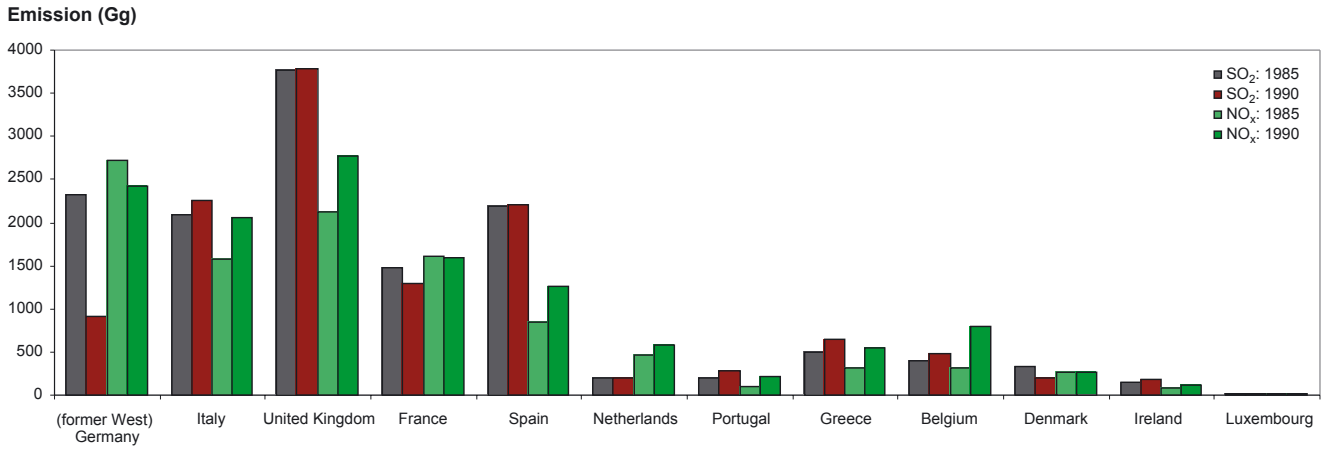
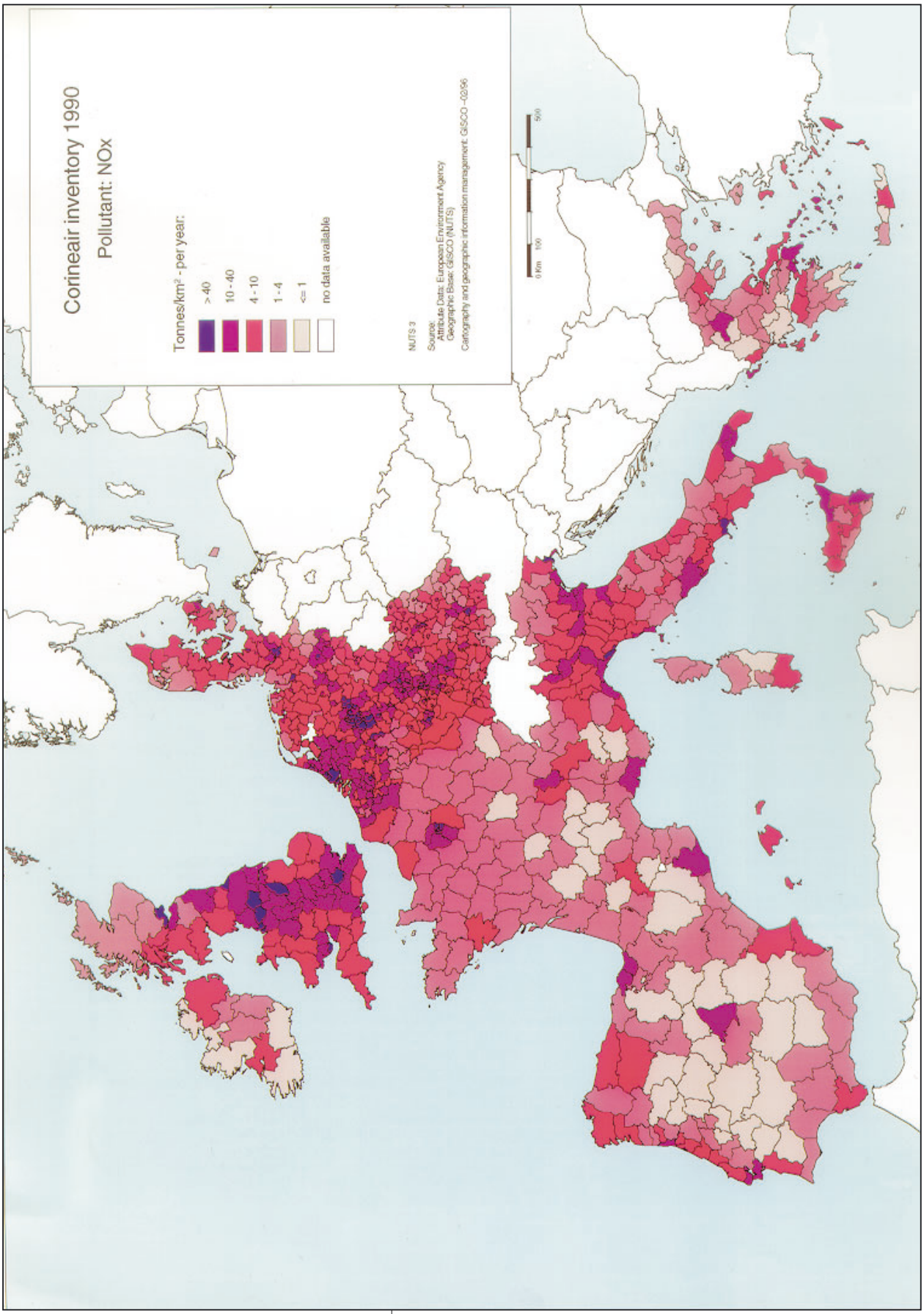


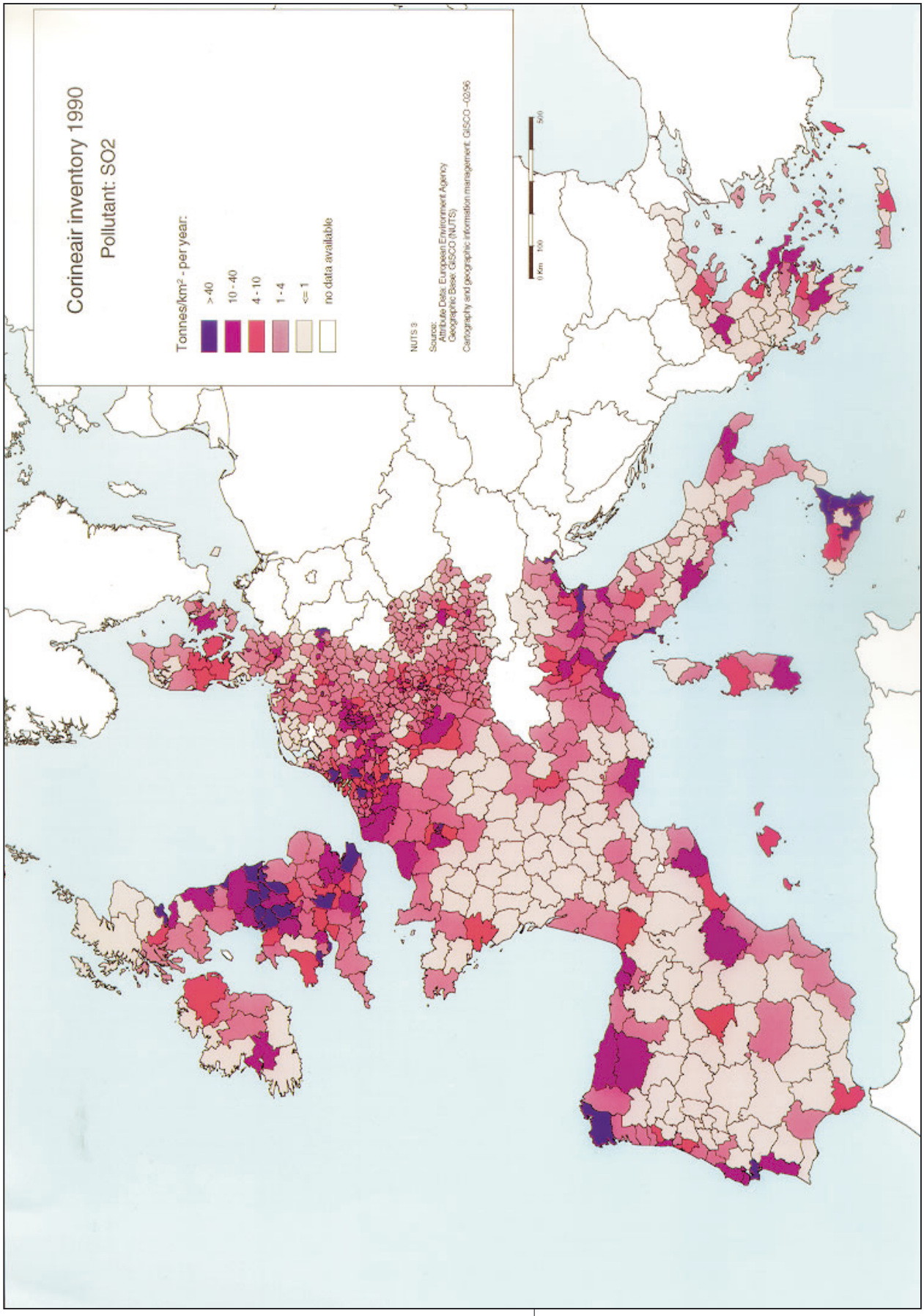
Figure 5 Emissions in the 12 1985 EU member states in 1985 and 1990.



3.4 Geographical distribution of emissions

→ At this position within the report a number of maps, to be produced by the GIS at EEA should be inserted into the document. These maps are not available yet. Below two examples of such maps are presented.


Corineair inventory 1990
Pollutant: NOx
Tonnes/km² - per year:
> 40
10 - 40
4 - 10
1 - 4
<= 1
no data available
NUTS 3
Source:
Attribute Data: European Environment Agency
Geographic Base: GISCO (NUTS)
Cartography and geographic information management: GISCO - 03/96
0 Km 100 500


Corineair inventory 1990
Pollutant: SO2
Tonnes/km² - per year:
>40
10 - 40
4 - 10
1 - 4
<= 1
no data available
NUTS 3
Source:
Attribute Data: European Environment Agency
Geographic Base: GISCO (NUTS)
Cartography and geographic information management: GISCO - 02/96
0 Km 500

4. Environmental burden by human activities

4.1 Environmental themes

This chapter analyses the data within the CORINAIR inventory with respect to the environmental burden caused by the emissions as stored in the CORINAIR database. In agreement with the Dobris assessment [Ref. 4] and the choices of the Fifth Environmental Action Programme of the European Union (see [Ref. 7]) the environmental burden is expressed by means of "themes". Air emission data are relevant for four themes:

- **Climate change**: global warming as a result of increasing concentrations of certain gases in the atmosphere. Global warming is expected to take place as a result of the emissions of the "Greenhouse gases" (GHGs): carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs). CORINAIR 90 contains emission data on the first three greenhouse gases. Emissions of CFCs are not available in CORINAIR. According to the Montreal protocol and the Copenhagen Amendment, the production of CFCs in the European Union will be phased out by 1996. As a result of this, the contribution of CFCs to climate change will decrease in the coming 10 to 15 years. In this report the contribution of CFCs to climate change is not taken into account.
- **Ozone depletion**: due to the emissions of CFCs and hydro fluorocarbons (HCFCs) the stratospheric ozone layer has been considerably depleted over the last 20 years. CORINAIR 90 does not have information available on the emissions of these components, hence this theme will not be discussed in this report. The theme indicator as used in [Ref. 4] and [Ref. 7] is based on the production and use of these compounds and not on the emissions.
- **Acidification**: the pollutants sulphur dioxide (SO_2), nitrogen oxides (NO_x) and ammonia (NH_3) undergo chemical reactions in the atmosphere and – after deposition – on the surface, resulting in acid substances. These substances seriously threaten the quality of soil and water and can have serious effects on species biodiversity and water and terrestrial ecosystems. The CORINAIR 90 inventory contains emission data on all relevant pollutants for this theme.
- **Air quality**: primary pollutants, emitted into the atmosphere, become part of a complicated (photo)-chemical reactive mixture of agents, which is partly driven by solar radiation and is greatly influenced by meteorological conditions. In summer this may result in high tropospheric ozone concentrations (summer smog). In winter when emissions of combustion related pollutants are high, unfavourable weather conditions may prevent the dispersion of the pollutants and give rise to very high ambient pollutant concentrations (winter smog). Pollutants contributing to this theme are sulphur dioxide (SO_2), nitrogen oxides (NO_x), hydrocarbons (VOCs) and particulate matter. In addition the emissions of heavy metals and persistent organic pollutants (POPs) may yield health problems. CORINAIR 90 does not contain emission data for the last two categories of pollutants. However they will be included in the CORINAIR 94 inventory.

Given the available information within the CORINAIR 90 database, this chapter will concentrate on the environmental burden by the emissions of GHGs (climate change) and on the emissions of pollutants causing acidification. Tropospheric ozone (summer smog) will not be touched upon. Discussion of this theme needs much more detailed information and assessment (high temporal resolution, speciated VOC-emissions, highly detailed meteorological data).

Apart from the four themes mentioned above, air pollution is one of the causes of forest degradation. However the present available surveys do not readily permit cause-effect relationships to be identified. Therefor this theme is not discussed in this report.

Table 7 Main sector split of European total emissions of greenhouse gases and acidifying components.

Main SNAP sector	GHGs (Ceq)	Acids (Aeq)	GHG's (%)	Acids (%)
Public power, cogeneration and district heating plants	1,364,249,000	549,501	24	35
Commercial, institutional and residential combustion	879,157,000	111,837	15	7
Industrial combustion	1,160,119,000	271,100	20	17
Production processes	295,573,000	47,513	5	3
Extraction and distribution of fossil fuels	282,071,000	3,195	5	0
Solvent use	378,000	35	0	0
Road transport	709,947,000	193,526	12	12
Other mobile sources and machinery	141,345,000	67,818	2	4
Waste treatment and disposal	301,867,000	15,457	5	1
Agriculture	617,195,000	310,813	11	20
Nature	726,580,000	25,784		

Right side of the table gives percentage contributions for anthropogenic emissions only

Figure 6 Main sector split of anthropogenic emissions of acidifying pollutants and greenhouse gases in Europe 1990 (%).

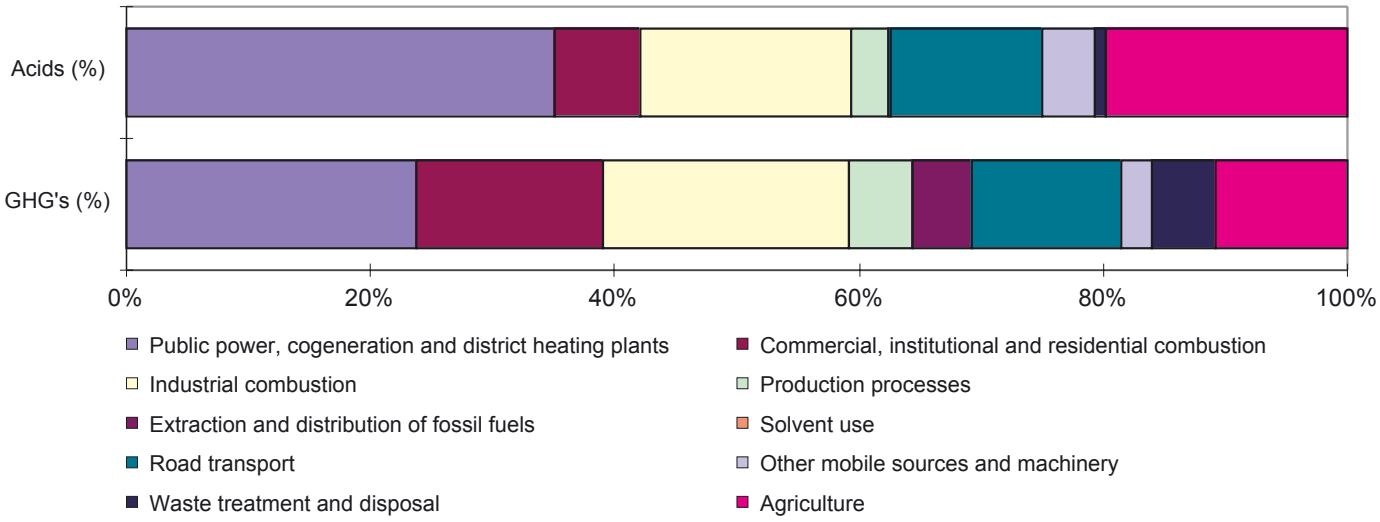


Table 7 presents the European total emissions expressed as greenhouse gas and acidification equivalents respectively. This chapter will deal with anthropogenic emissions only and thus excluding emissions from nature for two reasons:

- environmental burden caused by natural processes cannot be directly subjected to environmental policy decisions.
- data on natural emissions are not very reliable within the CORINAIR 90 database and national differences in methodology occur between participating countries.

Figure 6 shows the distribution of the emissions in graphical form for the anthropogenic emissions only. The following conclusions are drawn:

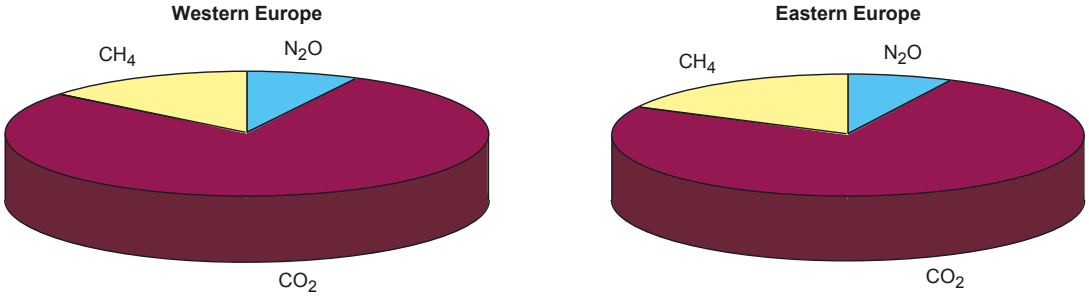
- About 60% of the emissions of acidifying pollutants and of GHGs occur in stationary combustion in **public power** and in industry and commercial and residential combustion.
- **Public power, cogeneration and district heating** alone is responsible for over one third of the emissions of acidifying pollutants and almost one quarter of the GHG emissions.
- **Road traffic** contributes about 12% to both GHG emissions and to acidification.
- **Agriculture** is an important source of acidifying pollutants (about 20%) and of GHGs (10%).

4.2 Climate change

Contributions per pollutant

The main pollutant contributing to global warming is CO_2. CH_4 and N_2O however also are important because of their high Ceq value. Figure 7 shows this for Western and Eastern European countries respectively. Both groups of countries show a comparable share of the individual pollutants to GHG emissions. About three quarters of the GHG emissions are attributable to the emissions of CO_2, about one fifth to CH_4 and about 10% to N_2O. The contribution of the latter two pollutants is in Eastern Europe somewhat larger.

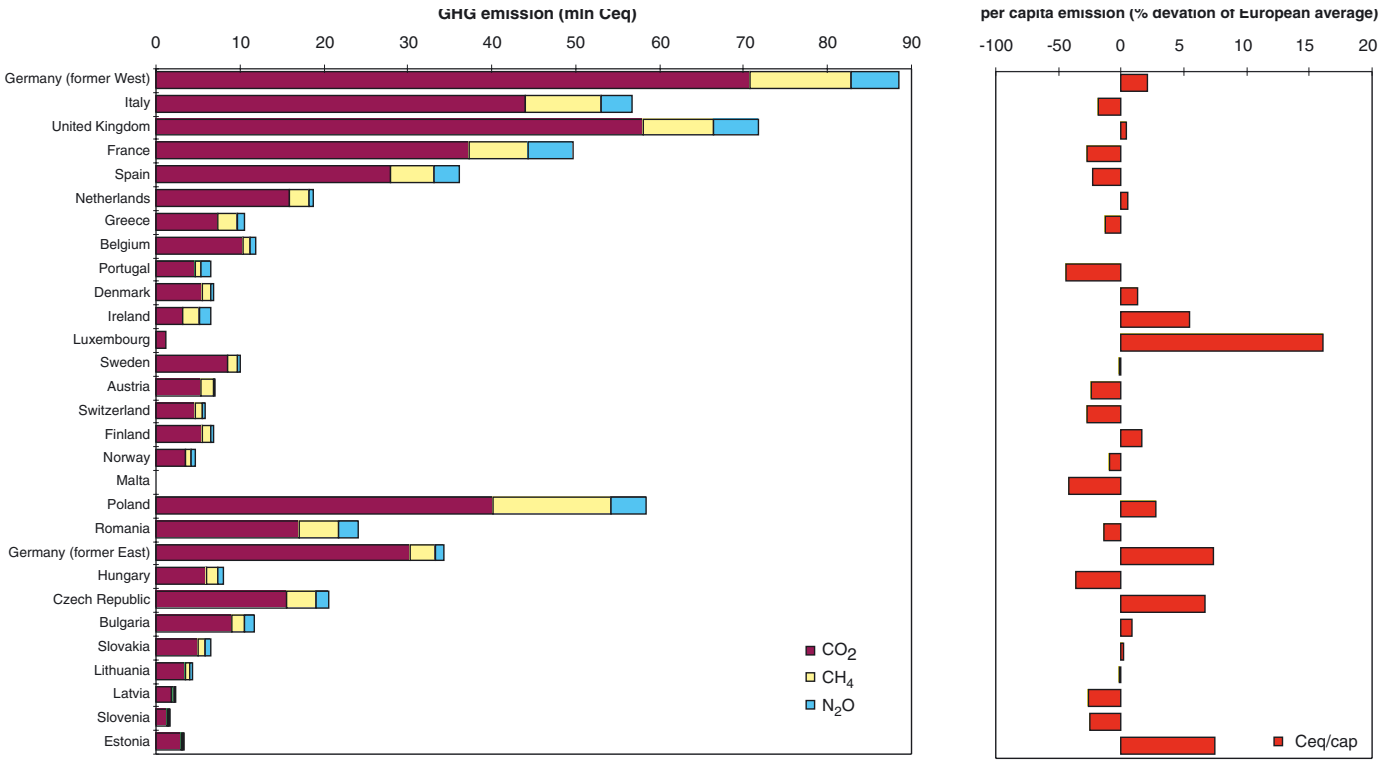
Figure 7 Contributions by different pollutants to greenhouse gas emissions in Western (left) and Eastern European countries (right); anthropogenic emissions only.



Contribution per country

Figure 8 shows national total emissions of GHGs per pollutant (left graph). It is clearly shown that the higher populated countries report the higher emissions of greenhouse gases. The right part of Figure 8 shows the per capita emissions for each country. The per capita emissions are expressed as deviations from the European average. The highest GHG emissions per capita occur in Luxembourg due to high industrial CO_2 emissions (steel production).

Figure 8 National totals of anthropogenic emissions of Greenhouse gases in 1990. Left: absolute values; right: per caputa emissions, relative to the European average.



Contribution per main sector

Figure 9 presents the contributions of the main SNAP sectors to emissions of greenhouse gasses in all participating countries. The general pattern as already observed in Table 7 appears for most countries:

- The contribution by stationary combustion sources varies in most countries between 50 and 70%. The only exceptions are Sweden and Ireland.
- The Central and Eastern countries all show large contributions from stationary combustion sources.
- In the majority of Central and Eastern European countries the contribution from road traffic is relatively low (about 5%) as compared with the Western European countries nearly (15%).

A few remarkable differences between countries however also can be seen:

- In Ireland a high contribution by agriculture is observed.
- Sweden reports important contributions of GHG emissions by waste treatment and disposal.
- Switzerland, Sweden and Norway show very low contributions from public power, cogeneration and district heating plants. This is consistent with the high use of hydropower in these countries. Also the contribution of this source is relatively low in France, due to the high contribution of nuclear power in this country.
- Greece, Spain and Portugal have the lowest relative contribution from commercial, institutional and residential combustion, which agrees with the southerly position of these countries on the map of Europe. The low contribution of these sources in Finland, Sweden and Norway, might be related to the low population density in these countries and a high share of electric heating.

4.3 Acidification

Contribution per pollutant

Three pollutants contribute to emissions of acidifying components: SO_2, NO_x and NH_3. Figure 10 shows the importance of each of these pollutants to the emissions of acidifying substances in both Western Europe and in Eastern Europe. In Eastern Europe by far the largest contribution to the emissions of acidifying pollutants is caused by SO_2. In Western Europe the emissions of NO_x and NH_3 are relatively much more important.

Contribution per country

Figure 11 presents national total emissions of acidifying pollutants. Most Western European countries report below average per capita emissions of acidifying pollutants, whereas most Eastern European countries report above average per capita emissions of these pollutants. The exceptions in Western Europe are Greece, Ireland, Denmark, Luxembourg and the united Kingdom. The exceptions in Eastern Europe are Romania and Latvia.

Contribution per main sector

The main sector splits per country for the emissions of acidifying components is given in Figure 12. The following observations can be made:

- In most countries stationary combustion sources are the main sources of acidifying pollutants (40 to 80%). The exceptions are Ireland, Switzerland, Norway and Sweden (20 to 30%).
- Agriculture contributes between 10 and 20% to national total emissions of acidifying pollutants in all countries except Ireland, where its share is almost 50%
- Mobil sources contribute relatively more in Western European countries (18%) as compared to Eastern European countries (4%) to the emissions of acidifying pollutants.

Figure 9 Per country main sector splits of anthropogenic emissions of greenhouse gases (%).

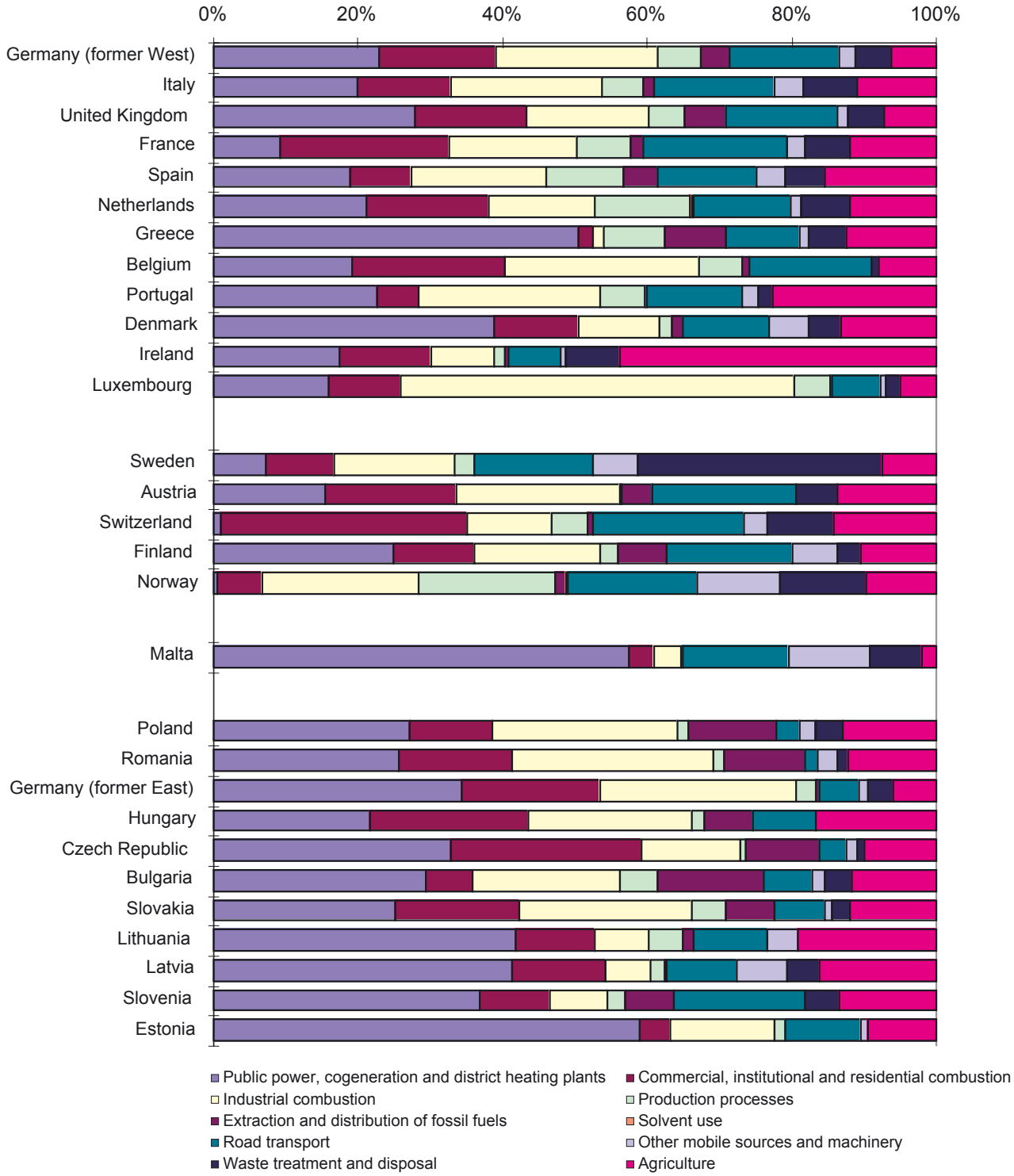


Figure 10 Contributions of different pollutants to anthropogenic emissions of acidifying components in Western (left) and Eastern European countries (right).

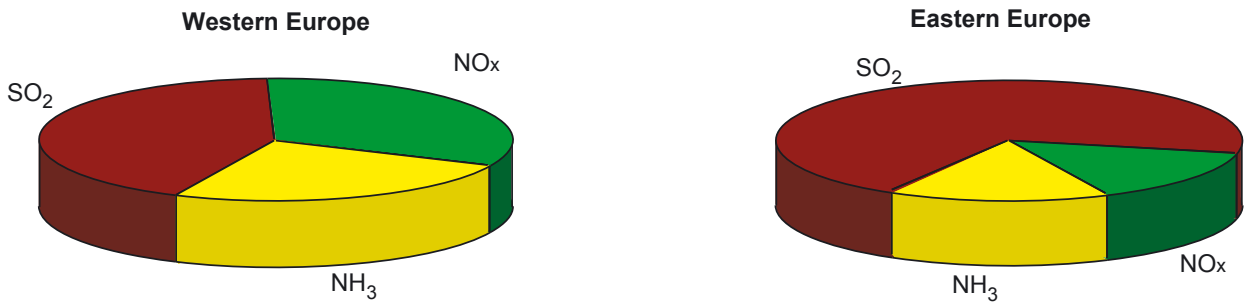


Figure 11 National totals of anthropogenic emissions of acidifying pollutants in 1990. Left: absolute values; right: per capita emissions, relative to the European average.

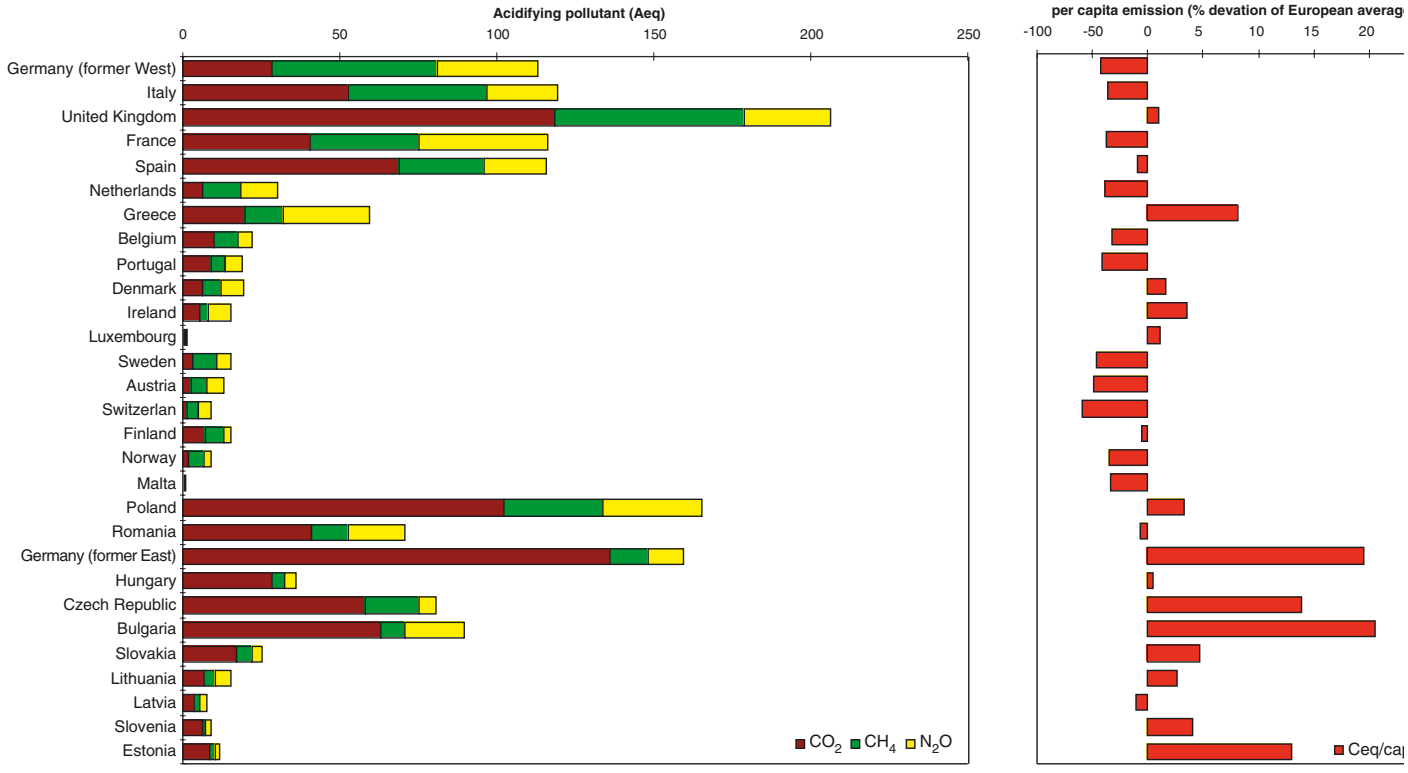
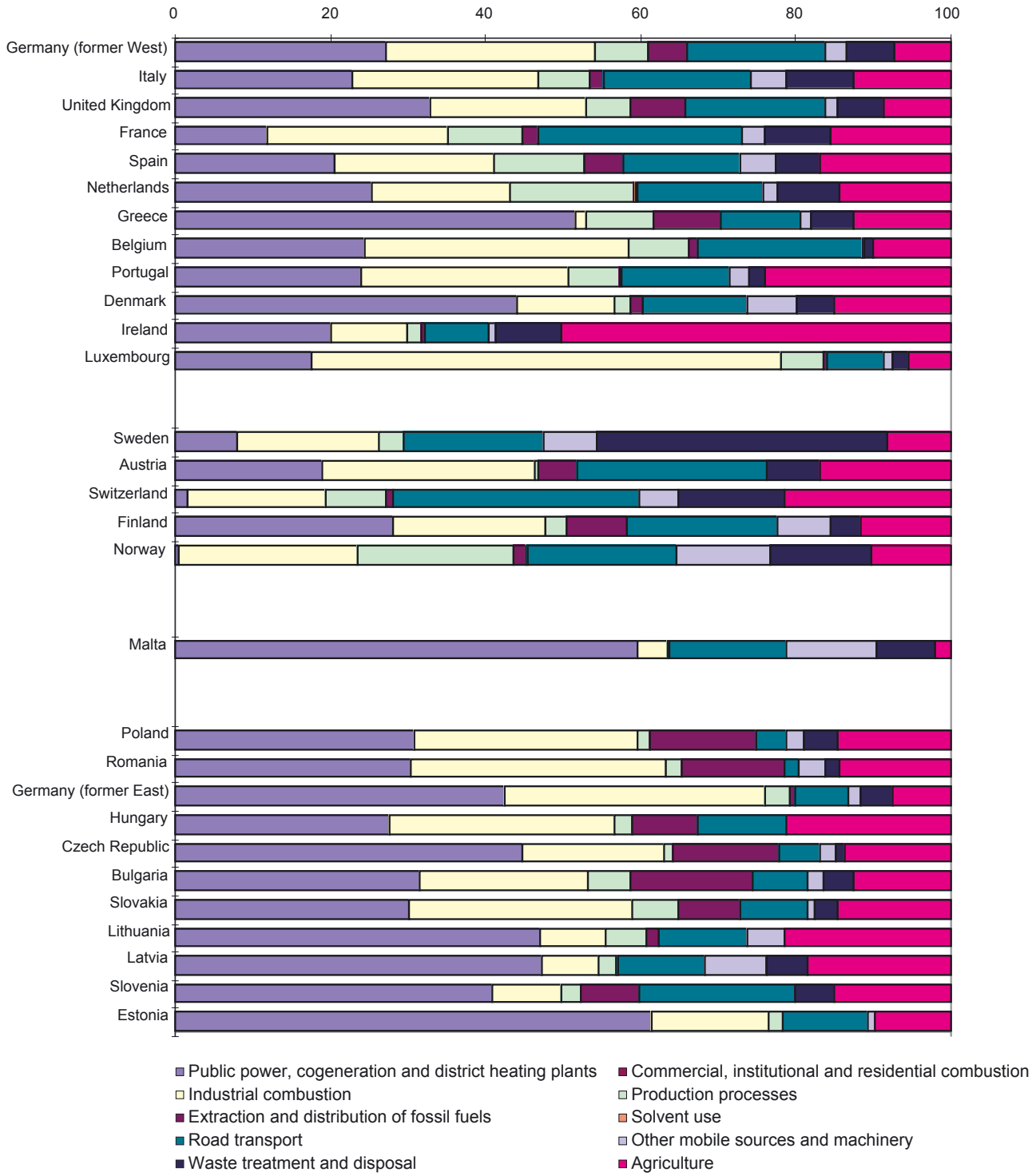


Figure 12 Per country main sector splits of emissions of acidifying pollutants (%)



5. Economic sectors

5.1 Introduction

This chapter presents the emissions as reported for a number of economic activities. These economic activities are related to the target sectors as defined in the Fifth Environmental Action Programme [Ref. 6]:

- **Industry**: this sector covers the manufacturing companies, including ores and metals, non-metallic minerals, refineries, chemicals, textile and clothing, pulp and paper and many others. Within CORINAIR most of the industrial sources are found within the main sectors 3, 4, 5 and 6 (partly, see Table 2). As has been shown in chapter 4 industrial sources contribute significantly to environmental burden. Paragraph 5.2 will present the emissions by several selected industrial branches and processes.
- **Transport**: road, rail, aviation and shipping transport are major activities with respect to environmental burden. As has been shown in chapter 4 road traffic in particular is important for both the emissions of GHGs and of acidifying pollutants. Section 5.3 will mainly concentrate on the emissions to the air by road traffic.
- **Energy**: the production and consumption of electricity and heat (energy consumption) results in a number of environmental problems, of which the emissions to the air are the most important. Main emission sources within this target sector are the fossil fuel fired power plants. Paragraph 5.4 will describe the emissions from public power plants in Europe.
- **Agriculture and forestry**: about 80% of the land in the European Union is used by agriculture and forestry. These activities cause important emissions to air. These will be presented in paragraph 5.5.

The other two target sectors (tourism and households [Ref 6, 7]) will not be dealt with in this report. The emissions to air of tourism are mainly due to transportation and are as such described in paragraph 5.3. Air emissions from households are related to combustion (residential heating and cooking), the use of private cars and of the use of paints and solvents. This report does not present results of the CORINAIR inventory with respect to these target sectors separately.

5.2 Industry

All industrial sources

Within industry a great variety of processes is used to produce a vast range of products. Almost all of these processes use some form of energy, either by the combustion of fuels or through the use of electric power. In addition emissions will occur due to the processes themselves. Chemical reaction might give rise to emissions to the air of a number of different pollutants, either because the gaseous waste products of the process are directly allowed to escape to the ambient air, or because of leakages of valves, pumps and so on. These emissions are stored in CORINAIR in the main SNAP sectors Industrial Combustion (SNAP 03) and Production Processes (SNAP 04) respectively. A further group of emissions that can be attributed to industrial activities are emissions related to the use of solvents (SNAP 060101, 060102 and 0603). Within other SNAPs more industrial emissions occur. Of those only the ones indicated in Table 8 are included in the analyses in this section. Industrial emissions occurring within Extraction and distribution of fossil fuels (SNAP 05) and mobile sources (SNAP 07 and 08) are not included in this section.

Table 8 presents the industrial emissions in Europe. The high energy use in industrial production is reflected in the high share these emissions have in the European totals of the combustion related pollutants. Almost 30% of all European SO_2 and CO_2 emissions are due to industry.

Figure 13 shows the relative share of both main sectors and of industrial solvent use as to the total emissions from industry. The following conclusions are drawn:

- Combustion processes are the major source of industrial emissions of SO_2, NO_x, CO_2, CO and CH_4.
- Two thirds of all industrial emissions of NMVOCs are attributed to the industrial use of solvents. The other part is largely due to process emissions.
- Almost all industrial emissions of NH_3 and N_2O are process emissions.

Table 8 Industrial emissions in Europe in 1990 (Gg); SNAP 03, 04, 060101, 060102, 0603

Sector	SO_2	NO_x	NMVOC	NH_3	N_2O	CO_2	CO	CH_4
Industrial combustion	6,968	2,439	154	1	54	1,140,655	8,200	92
Production processes	923	392	1,220	172	356	179,915	3,188	76
Industrial solvent use	0	1	1,524	0		0	1	0
European industry	7,891	2,831	2,898	174	409	1,320,570	11,389	168
Share in European total (%)	28.3	15.8	13.3	3.0	21.8	27.7	16.3	0.4

Figure 13 Relative contribution of emissions caused by combustion, process and solvent use within industry in 1990 (%)

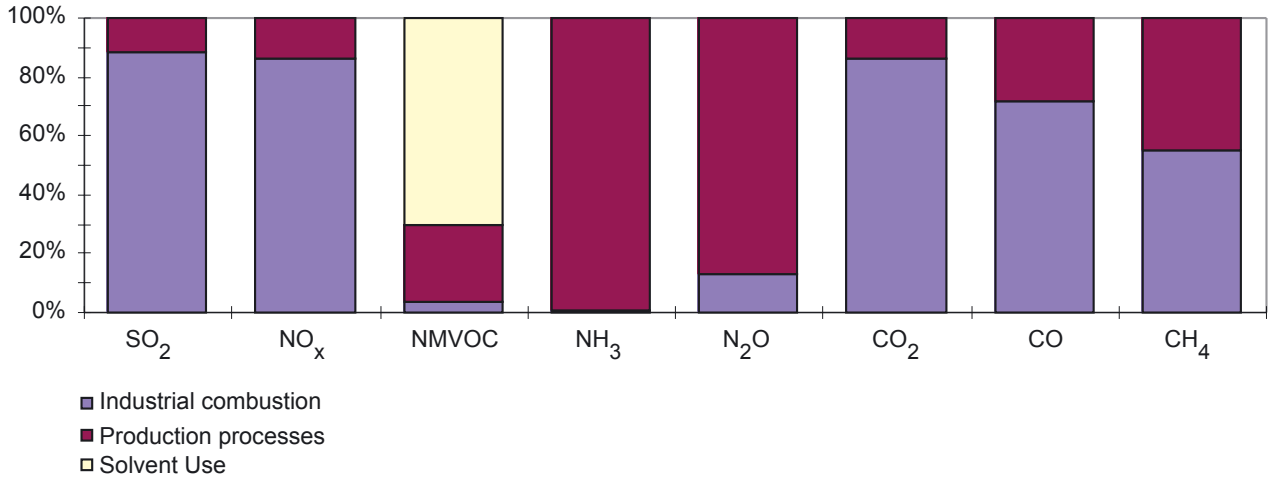


Figure 14 Distribution of the industrial emissions of GHGs and acidifying pollutants (Aeq) over combustion, process and solvent use emissions in 1990 (%).

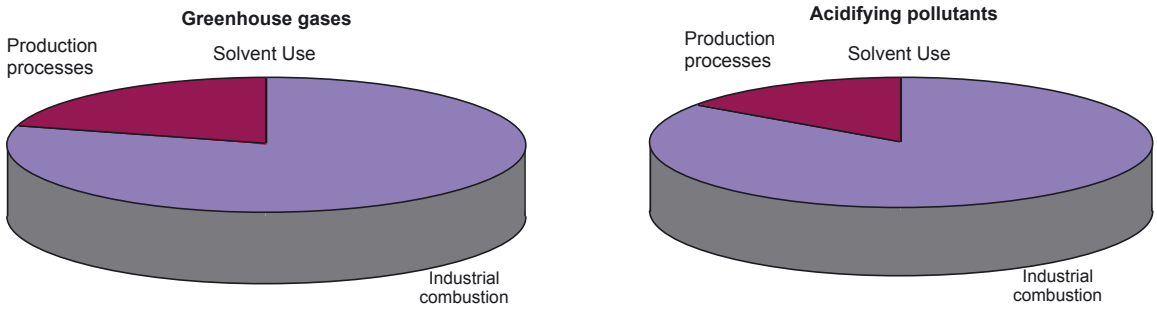


Figure 14 shows the contribution of combustion and process emissions to the industrial emissions of GHGs and acidifying pollutant. The major part of the environmental burden in these two themes is due to combustion (75 to 80%)

Industrial combustion

As has been indicated above for many pollutants combustion in industry gives a major contribution to the emissions within this target sector and contributes significantly to the European totals. Table 9 presents these emissions. The large share of combustion processes in the European total emissions is apparent.

Comparing the emissions in Western and Eastern Europe, the differences in fuel quality are visible. Although the CO_2 and NO_x emissions in Eastern Europe are about 50 and 60% of those in Western Europe, the SO_2 emissions are higher in Eastern Europe (115% of SO_2 emissions in Western Europe). Sulphur contents in fuels in Eastern Europe are higher and flue gas desulphurization is less available in this part of Europe.

Industrial emissions in each country is expected to be dependent upon the industrial production in that country. Figure 15 shows this relation by means of a linear regression analysis between industrial production (in millions US$) and the emissions of GHGs and acidifying pollutants from industrial combustion. A fairly high correlation is observed for GHGs. Eastern European countries tend to emit more GHGs per US$ industrial production than the Western European countries, reflecting a better energy efficiency in the latter part of Europe. The correlation for the emission of acidifying pollutants is much lower. The influence of different fuel characteristics in different countries apparently disturbs the relation. Most Eastern European countries tend to emit more acidifying pollutants than Western Europe per dollar earned in industrial production.

Figure 16 shows the contribution by different sizes of industrial combustion plants. The largest contribution is due to the smaller types of plants (< 50 MWth). The largest plants appear to have relatively low CO emissions, whereas gasturbines and stationary engines have relatively high NO_x emissions.

Table 9 European emissions from industrial combustion in 1990 (Gg); SNAP 03

	SO_2	NO_x	NMVOC	NH_3	N_2O	CO_2	CO	CH_4
Western European countries	3,239	1,524	75	1	34	742,177	2,976	51
Eastern European countries	3,729	915	79	1	19	398,478	5,224	41
European industrial combustion	6,968	2,439	154	1	54	1,140,655	8,200	92
Share in European total (%)	25.0	13.6	0.7	0.0	2.9	23.9	11.8	0.2

Figure 15 Relation between GHG (left) and acidifying pollutants (right) emissions and industrial production in 1990 (logarithmic scales).

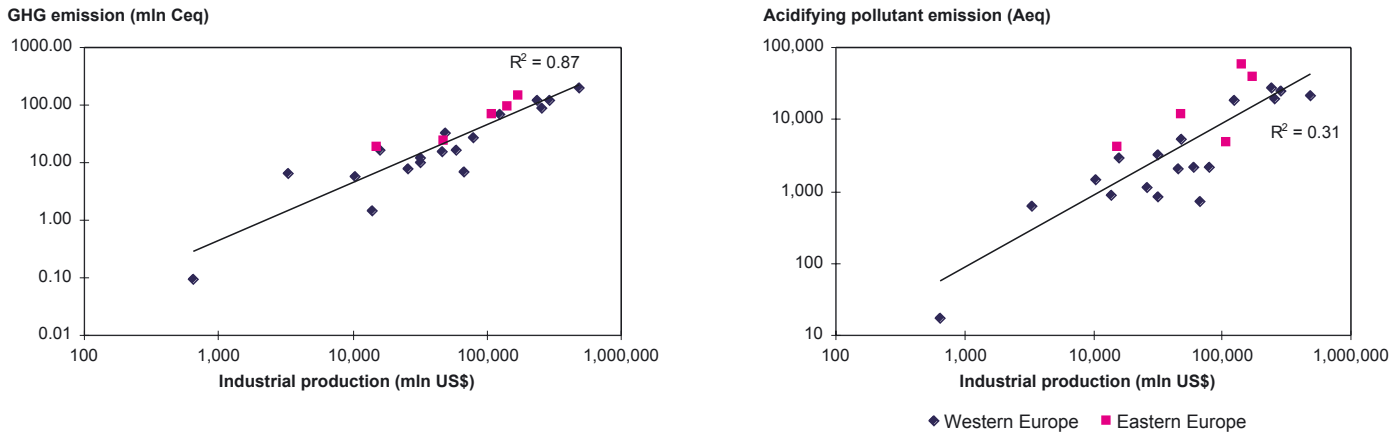
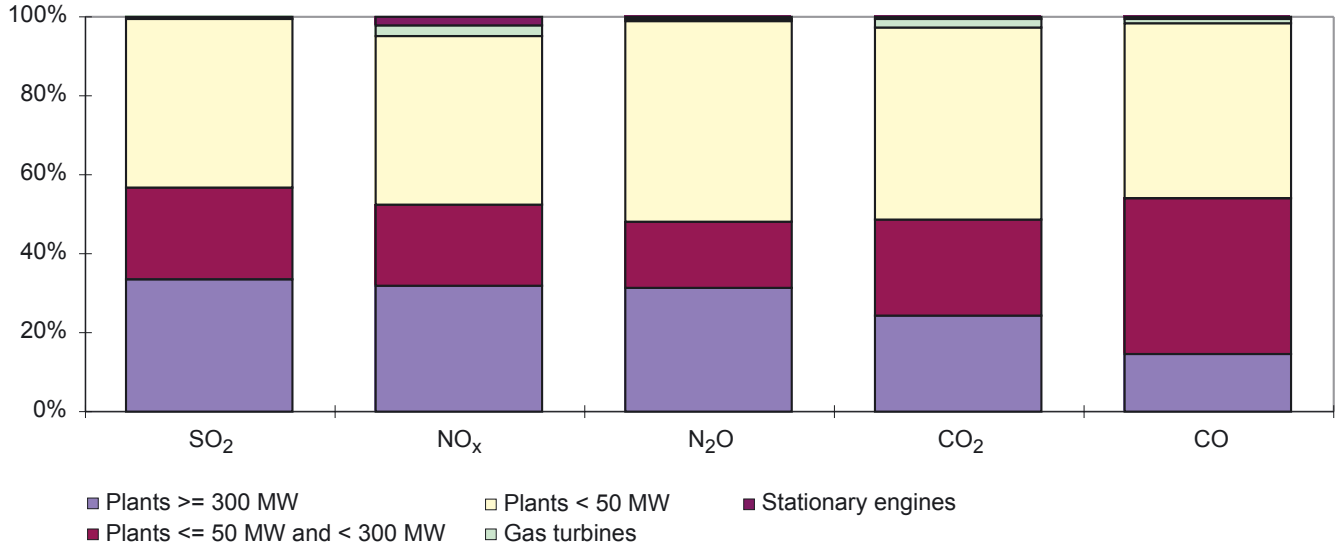


Figure 16 European total emissions due to industrial combustion per type of installation (%).



Process emissions

The CORINAIR 90 database contains the emissions of industrial processes with a high level of detail. This paragraph present as examples the emissions by two specific processes: sinter plants and cement production.

Sinter plants

The sintering process converts fine-sized raw materials, including iron ore, coke breeze, limestone, mill scale, and flue dust, into an agglomerated product, sinter, of suitable size for charging into the blast furnace. The raw materials are sometimes mixed with water to provide a cohesive matrix, and then placed on a continuous, travelling grate called the sinter strand. A burner hood, at the beginning of the sinter strand ignites the coke in the mixture, after which the combustion is self supporting and it provides sufficient heat to cause surface melting and agglomeration of the mix [Ref. 15]. The emissions to the air in Western and Eastern Europe in 1990 are given in Table 10. This process contributes about 5% to the total European CO emissions and 1.3% to those of SO_2.

Cement production

The majority of cement production is concentrated on two types of cement: portland cement and blast furnace cement. In general, portland cement is produced from raw cement clinker which is being fired in a rotary kiln, and gypsum anhydrite. This process is followed by a dry milling and shipment. Blast furnace cement is produced by milling fired cement clinker, pre-dried blast furnace slag and gypsum anhydrite. The handling of raw materials, on site transportation, firing clinker, milling and shipment give rise to dust emissions [Ref. 15]. These emissions are not inventoried in CORINAIR.

Cement production is an important source of CO_2 and NO_x emissions. Table 11 presents the emissions by cement production (SNAP 030311) in 1990. It is shown that this industrial process accounts for over 2% of the total European emissions of both NO_x and CO_2. Emissions of the other pollutants are negligible on a European scale but might be significant locally.

Table 10 Emissions in Sinter plants in 1990 (Gg); SNAP 03 03 01

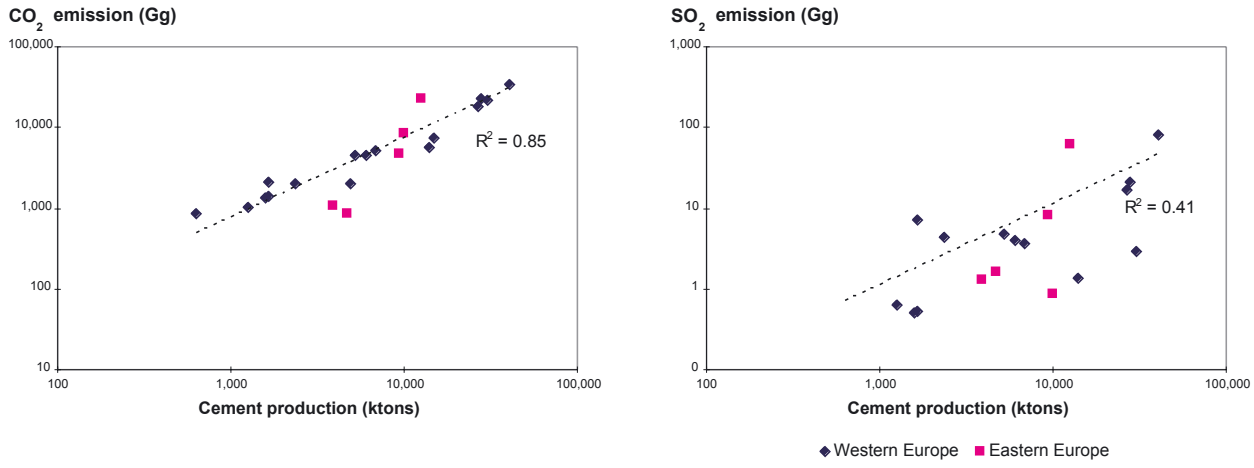
	SO_2	NO_x	NMVOC	N_2O	CO_2	CO	CH_4
Western Europe	112	72	6	0	13,099	1,598	15
Eastern Europe	245	105	14	0	7,122	1,785	15
European sinter plants	357	177	19	1	20,221	3,383	30
Share in European total (%)	1.3	1.0	0.1	0.0	0.4	4.9	0.1

Table 11 National total emissions (Gg) by cement production (SNAP 03031) in 1990

	Cement production	SO_2	NO_x	NMVOC	N_2O	CO_2	CO	CH_4
Western Europe	186,707	150	306	4	4	134,149	41	4
Eastern Europe	40,629	91	142	1	1	48,484	75	1
European cement production	227,336	242	447	5	5	182,633	115	5
Share in European total (%)		1	2	0	0	4	0	0

Figure 17 shows the relation between the emissions of CO_2 and SO_2 respectively and the cement production in each country. A reasonable correlation is observed for CO_2 emissions for most countries, both in Eastern and in Western Europe.Correlation between cement production and SO_2 emissions is poorer. No clear differences between Western and Eastern European countries are observed.

Figure 17 Correlation between cement production and emissions CO_2 and SO_2 in 1990 (logaritmic scales).



5.3 Transport

All modes of transport

Transport is important for emissions of all pollutants except CH_4 and NH_3. Table 12 presents the contributions from the different modes of transport to the European total emissions. Road transport (SNAP 07) is the major cause of air pollutants from this target sector for all pollutants. Shipping (SNAP 08 03 and 08 04) causes nearly 25% of the transport related SO_2 emissions and almost 10% of those of NO_x. This observation is consistent with the fact that in shipping, especially sea-going vessels, higher sulphur contents in fuels are used The contribution of off road vehicles and machinery amounts to 5 to 15% for all pollutants. The following section will analyse the emissions caused by road traffic.

Table 12 Emissions from the target sector Transport (SNAP 07 + 08) in 1990 (Gg)

	SO_2	NO_x	NMVOC	N_2O	CO_2	CO
Road Transport	718	7,846	6,766	30	695,499	38,919
Off road vehicles and machines	153	1,147	418	3	73,120	1,690
Railways	40	199	33	0	13,768	84
Shipping	351	785	155	2	34,057	275
Air traffic (LTO + taxying)	20	179	71	1	17,789	174
Total transport	**1,283**	**10,156**	**7,442**	**36**	**834,233**	**41,143**
Share in European total (%)	4.6	56.7	34.2	1.9	17.5	59.0

Road transport

Table 13 presents the emissions by road traffic in Europe as stored in the CORINAIR90 database. Road traffic accounts for more than half of the total European CO emissions and is also very important for the NO_x and NMVOC emissions. The high energy use within this activity is reflected in the 15% share of road traffic in the total European CO_2 emissions.

CORINAIR 90 recognizes 6 different subsectors within the main sector Road Traffic, representing the different types of vehicles and evaporation of fuels. Figure 18 represents the share of each of these subsectors to emissions from road traffic. Passenger cars are the main source of all emissions except SO_2. They are especially important with respect to the emissions of CO. Heavy duty vehicles and buses are important for the emissions of SO_2, NO_x and CO_2.

The number of vehicles in a country, and the use of it might correlate with the number of cars and with the number of inhabitants in a country. Figure 19 presents the emissions of GHGs and acidifying pollutants in each of the participating countries as a function of the size of the car fleet and the size of the population. A high correlation ($R^2 > 0.95$) with the car fleet is observed. The Central and Eastern European Countries tend to show higher road traffic emissions per car as compared to the Western European countries. The correlation with the size of the population is weaker, but still rather high ($R^2>0.85$). Now however the Eastern European countries show lower emissions from road traffic per capita than the Western European countries. These results agree with the smaller number of cars per inhabitant in Eastern Europe and with the fact that the cars in that part of Europe are on the average older, which means that the emission per car is higher because the technology is less advanced.

Table 13 Emission by road transport in Europe 1990 (Gg)

	SO_2	NO_x	NMVOC	N_2O	CO_2	CO
Western Europe	521	6,833	5,648	26	614,215	33,100
Eastern Europe	198	1,013	1,118	4	81,283	5,820
European road traffic	718	7,846	6,766	30	695,499	38,919
Share in European total (%)	2.6	43.8	31.1	1.6	14.6	55.8

5.4 Energy: Public power plants

As has been indicated in section 5.1 the most important activity within the target sector Energy is the generation of electric power in public power plants. This section describes the European emissions from public power plants (SNAP 01 01). Other activities in this main sector (district heating plants) are not covered in this section.

Figure 18 Distribution of emissions over the subsectors within road traffic in 1990 (%)

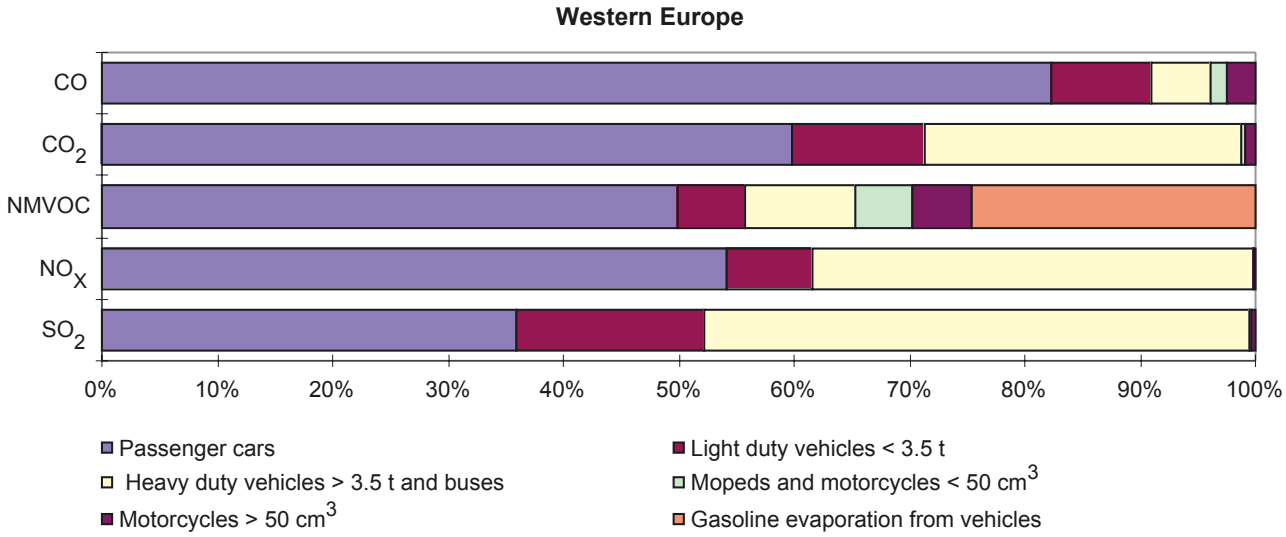


Figure 19 Correlation of road traffic emissions and number of cars (above) or size of the population (below) in each country.

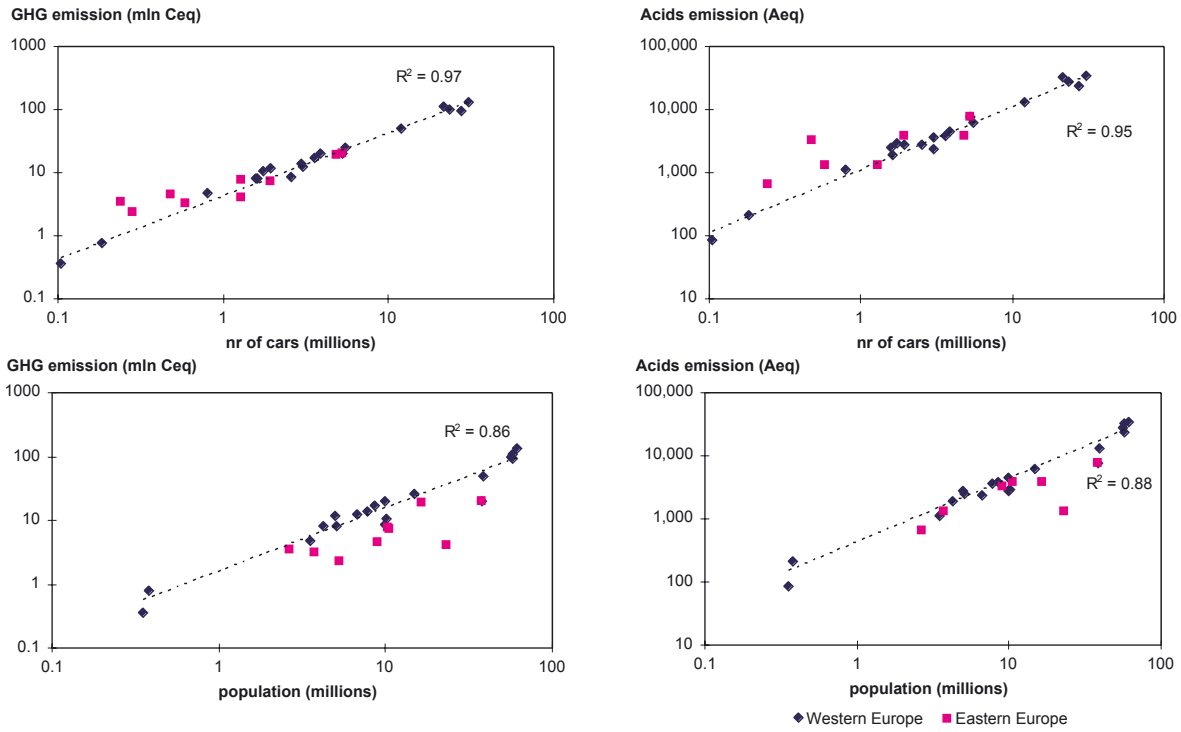


Table 14 presents the total emissions as stored in the CORINAIR90 database for Western and Eastern European countries respectively. More than half of the European emissions of SO_2, more than one quarter of the CO_2 emissions and about one fifth of the NO_x emissions are caused by public power plants.

Public power is an important activity in all countries, providing the electric energy (and partly some heat) for the country. In many countries power plants are fossil fuel fired, but the mix of fuels will vary among countries. The differences in fuel mix between both groups of countries are already apparent from this table: Although the CO_2 emissions in Western Europe are about 70% higher than in the Eastern European countries, the SO_2 emissions in these countries are 20% lower than in Eastern Europe.

Figure 20 shows the relation between electricity use and emissions of SO_2 and CO_2 in the participating countries. The countries with a high share in hydro-power (Norway, Switzerland and Sweden) show a low emission of CO_2 and SO_2 relative to their electric energy use. The correlation between SO_2 emission

Table 14 Emissions from power plants in Europe in 1990 (Gg)

	SO_2	NO_x	NMVOC	NH_3	N_2O	CO_2	CO	CH_4
Western Europe	6,389	2,273	36	0	53	794,143	174	24
Eastern Europe	7,832	1,300	11	1	39	455,182	526	13
European Public power	14,221	3,573	47	1	91	1,249,326	700	37
Share in European total (%)	51.0	19.9	0.2	0.0	4.9	26.2	1.0	0.1

and electricity use is rather weak, reflecting the important influence of fuel mix in the public power plants. Both graphs show also that Eastern European countries report relatively high emissions of CO_2 and SO_2 by public power plants, indicating a lower energy efficiency, a higher sulphur content in fuels and a lower penetration of desulphurization in equipment in these countries.

Within the CORINAIR system the public power plants are divided into 5 separate technologies:

- Combustion plants >= 300 MW
- Combustion plants >= 50 and < 300 MW
- Combustion plants < 50 MW
- Gas turbines
- Stationary engines

Figure 21 shows that over 90% of the emissions originates from the large plants (≥ 300 MW). Contributions by the other installation types are less than a few percent. This is completely different from industrial combustion as shown in Figure 16, where also smaller plants contribute significantly.

Figure 20 Emissions of CO_2 (left) and SO_2 (right) as a function of national final electricity consumption in 1990.

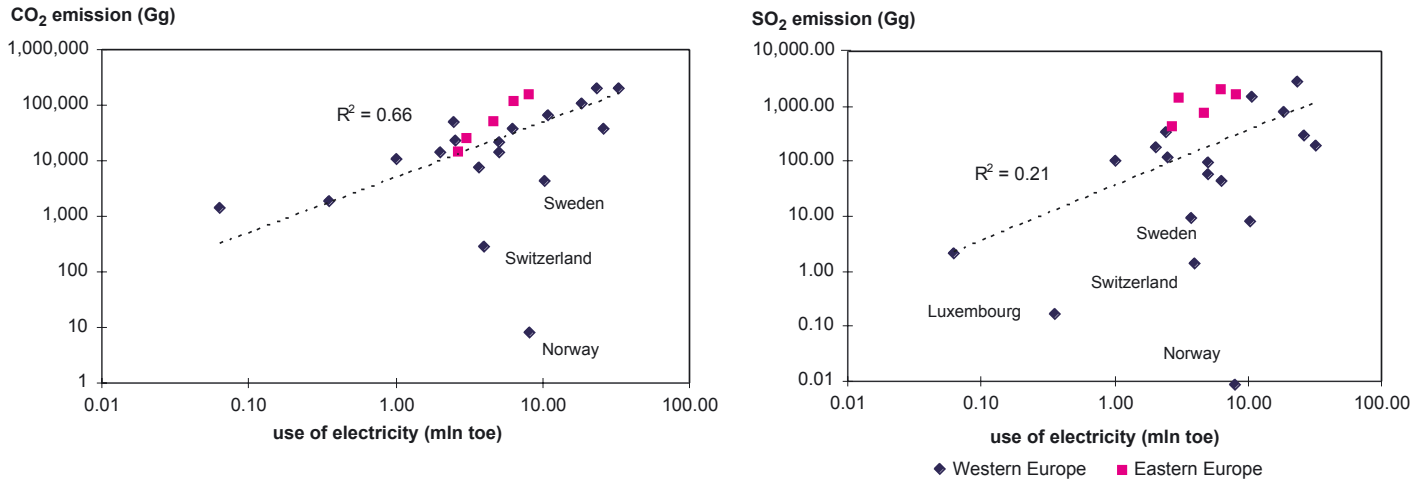
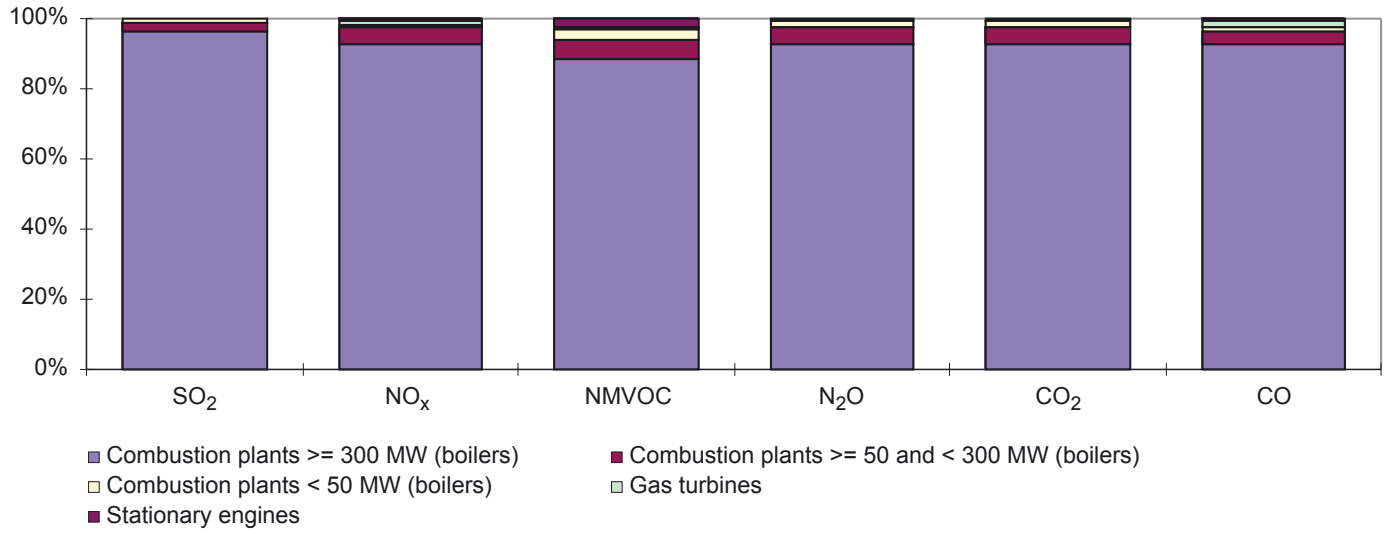


Figure 21 European total emissions in Public Power plants per type of installation (%).



5.5 Agriculture

Table 15 present the emissions caused by agriculture in Western and Eastern European countries. It is shown that over 90% of all NH_3 emissions occur from agriculture. About one third of the emissions of N_2O and CH_4 are originating from agriculture.
Emissions of the other pollutants by agriculture are negligible compared to the total emissions in Europe.

Figure 22 shows the relation between emissions of GHGs and acidifying pollutants and the number of economic active persons in agriculture. Correlations are quite weak. The emissions per active person in agriculture are higher in Western European countries as compared to the Eastern European countries. This reflects the higher productivity of Western European agriculture.

Table 15 Emission from agriculture in 1990 (SNAP 09, Gg)

	SO_2	NO_x	NMVOC	NH_3	N_2O	CO_2	CO	CH_4
Western Europe	1	37	641	3,662	463	21,296	579	10,173
Eastern Europe	0	12	117	1,604	263	1,154	1	4,620
European agriculture	1	50	759	5,267	726	22,450	579	14,793
Share of total Europe (%)	0.0	0.3	3.5	92.4	38.6	0.5	0.8	32.6

Figure 22 Correlation between number of economic active persons in agriculture and GHG emissions (left) and acidifying pollutant emissions (right).

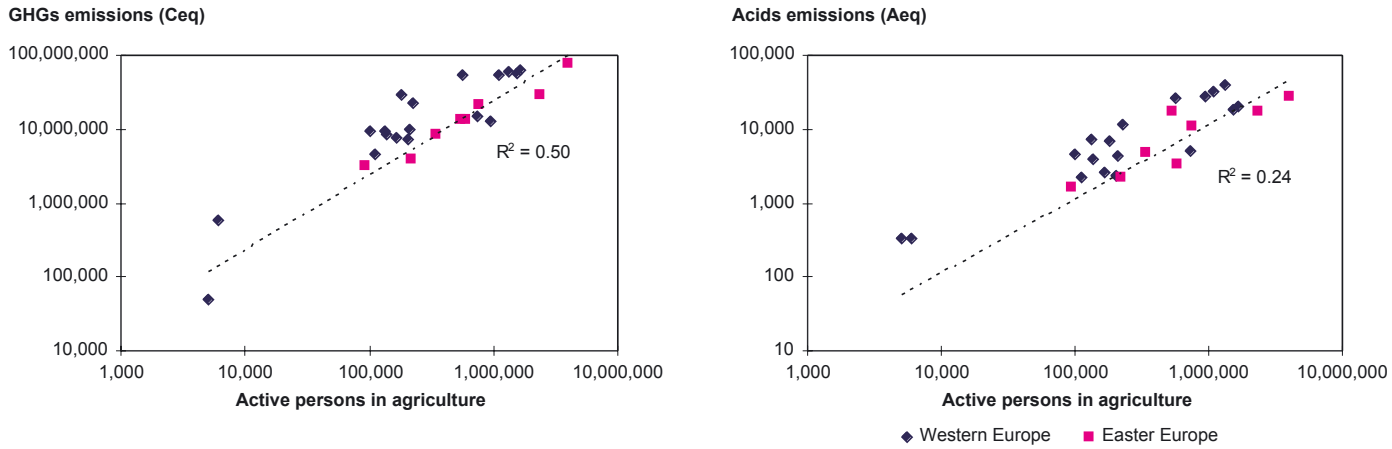


Table 16 Agricultural emission densities in European countries. Left: acidifying pollutants; right: greenhouse gases.

COUNTRY	Aeq/km^2	COUNTRY	Ceq/km^2
Malta	1.008	Netherlands	543
Netherlands	0.283	Belgium - Wallonie	421
Greece	0.206	Ireland	404
Denmark	0.172	Czech Republic	263
Belgium - Flemish	0.157	Poland	242
Bulgaria	0.153	Belgium - Flemish	238
Belgium - Wallonie	0.131	Luxembourg	226
Luxembourg	0.129	Germany (BRD)	219
Germany (BRD)	0.127	United Kingdom	215
United Kingdom	0.108	Denmark	213
Germany (GDR)	0.103	Switzerland	200
Ireland	0.100	Italy	198
Switzerland	0.093	Germany (GDR)	192
Poland	0.086	Portugal	162
Slovenia	0.078	Slovakia	158
Romania	0.073	Malta	157
France	0.073	Hungary	144
Lithuania	0.073	Lithuania	128
Slovakia	0.068	Bulgaria	123
Italy	0.066	Romania	122
Czech Republic	0.066	Slovenia	117
Portugal	0.055	Austria	116
Austria	0.053	Spain	110
Estonia	0.037	France	108
Spain	0.037	Greece	98
Hungary	0.036	Estonia	69
Latvia	0.034	Latvia	59
Finland	0.007	Finland	21
Norway	0.007	Sweden	17
Sweden	0.006	Norway	14

Countries also differ in the area related agricultural productivity.

Table 16 gives the spatial emission densities for all European countries for acidifying pollutants and greenhouse gases emissions by agriculture. Apart from Malta (which shows a very high acid emission per km2), the Netherlands show the by far highest emission intensities for both acidification and greenhouse gasses. This observation agrees with the high agricultural productivity in this country.

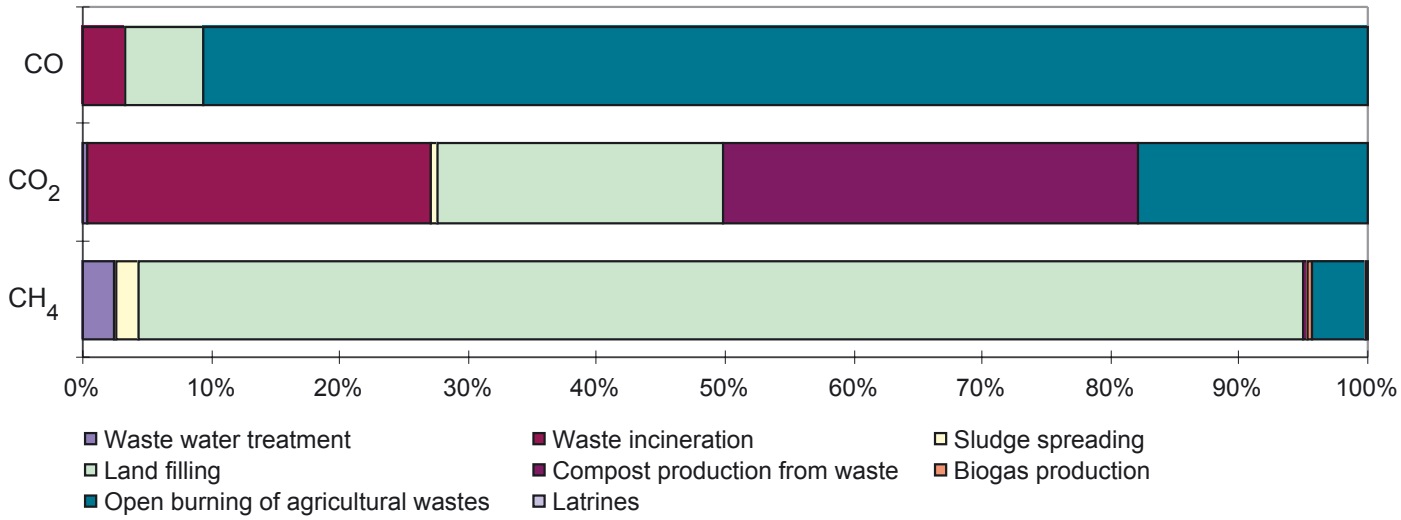
5.6 Waste treatment

Part of the wastes in Europe are incinerated, part of it is disposed of in landfills and part is being used in composting facilities. The emissions of these processes are summarized in Table 17. Nearly 20% of the European CH_4 emissions and over 6% of the CO emissions are due to this source sector. Minor contributions are observed for the other pollutants.

Figure 23 presents the contribution of different technologies (SNAP subgroups) to the emissions of CO, CO_2 and CH_4. It can be seen clearly that these different technologies have completely different emissions. Open burning of agricultural wastes contributes over 90% of the CO emissions within this sector. As far as the CH_4 emissions are concerned landfills are by far the most important. CO_2 is emitted by a number of processes: compost production, waste incineration, landfilling and open burning.

	SO_2	NO_x	NMVOC	NH_3	N_2O	CO_2	CO	CH_4
Western Europe	82	134	244	59	10	77,338	2,769	7,119
Eastern Europe	5	108	261	69	3	5,834	1,657	1,633
European waste treatment	87	241	506	128	13	83,171	4,427	8,752
Share in European total (%)	0.3	1.3	2.3	2.2	0.7	1.7	6.3	19.3

Figure 23 Contribution of different processes to emissions by waste treatment and disposal in 1990 (%).



6. Discussion and conclusions

This report presents the major results of the CORINAIR 90 emission inventory. This inventory contains emission data for 8 pollutants in 28 European countries for the base year 1990. The data have been compiled and collected by national experts within a methodology that was developed in close cooperation with the EMEP Task force on emission inventories, ensuring optimal correspondence with data to be delivered to the LRTAP Convention.

The data as available at the European Environment Agency have been analysed with respect to the environmental burden and to economic activities in correspondence with the choices made in the 5th European Environmental Action Programme [Ref. 6];

- environmental burden has been described using the concept of environmental themes and
- economic sectors are chosen within the target sectors as defined in this Action Programme.

The data within CORINAIR are shown to be very useful in describing the state of the environment using both the themes and the target sector approach.

The main objectives of the CORINAIR activity was to obtain transparent, consistent and complete emission information for all of Europe. Transparency was reached by using a harmonized methodology by all countries and by thoroughly screening and checking of the data delivered to EEA. This methodology helped national experts to recognize all possible emission sources within each country.

Consistency of the data

National total emissions and national sector splits have been correlated with socio-economic and geographic data. For many pollutants and many economic activities and sectors, high correlation coefficients were obtained. Especially emissions of CO_2, NO_x, CO and NMVOC show in many cases covariances above 0.9 with such parameters as size of the population, number of cars in use, energy requirements and economic production within the relevant sector. This suggests a high inter country comparability and consistency of these data: over 90% of the between country differences in emissions of these pollutants can be explained by these types of parameters.

For the pollutants mentioned above, about 10% of the between country variance in emissions might be due to differences in environmental policy or differences in technologies applied. Since in many cases policy targets for emission reductions are in the order of a few percents, these differences are relevant for use in environmental policy studies and in compliance checking. It is stressed here that the possibilities of abatement strategies to decrease the emissions are not limited to the 10% as mentioned here. It merely indicated the national averaged differences between countries in this respect.

In those cases where lower correlations between emissions and socio-economic or geographical data were observed, this can at least in part be explained by differences in the countries energy supply (fuel mix) and economic developments (level of technological development) or abatement technologies available within the country.

Environmental themes

This report shows that analysis of the emission data in CORINAIR 90 yields valuable information on the environmental themes of climate change and of acidification. For both themes stationary and mobile combustion processes are by far the most important contributors in all countries.

The environmental theme of climate change is strongly related with the energy demand and fossil fuel use. Differences between countries can be explained amongst others by the share of hydropower and nuclear power within the electric energy supply system.

Public power plants contribute to about 35% of the European emissions of acidifying pollutants. The SO_2 emissions are an important part of this, especially in Eastern Europe where fuels with higher sulphur contents are used. NH_3 from agriculture contributes about 20% to the total acidifying emissions in Europe.

The environmental theme of air quality cannot be studied in detail using the CORINAIR 90 database alone. To calculate summer smog and assess the contributions of emissions from the various activities, a high time resolution is needed and NMVOC emissions need to be speciated, which is not available in the database. The spatial distribution of total annual emissions available in CORINAIR 90 however can be disaggregated using modeling techniques. These and other assessments will be carried out by the EEA in collaboration with its Topic Centres on Air Quality and Air Emissions.

Emissions of toxics (heavy metals and persistent organic pollutants) are not available within CORINAIR 90. These substances however will be included in CORINAIR 94.

Target sectors

The emissions from a number of economic sectors have been analysed. The data within the CORINAIR 90 database appear to be consistent with (economic) production in these sectors.

Within industry, combustion is the major source of most pollutants present in CORINAIR 90. The major part of the NMVOC emissions however are due to the industrial use of solvents, whereas most industrial emissions of NH_3 and N_2O are related to production processes.

Emissions from combustion plants within industry are mainly originating from the smaller sizes (< 50 MW). emissions from combustion as applied within public power plants however are mainly resulting from large plants (> 300 MW).

Future developments

CORINAIR 90 has proven to be a successful activity. Most European countries participated in a coordinated effort to produce a complete and consistent emission inventory for the year 1990. Presently the European Topic Centre on Air Emissions is preparing the compilation of an inventory for the year 1994 together with national experts. This inventory will draw heavily on the experiences gained in the 1990 CORINAIR project. The number of pollutants in this new inventory will be increased by including heavy metals and persistent organic pollutants. The new inventory than can be used to analyse also the environmental theme of air quality with respect to these pollutants.

Countries are requested to provide data to different international gremia and organizations. A high degree of harmonization has been achieved between the CORINAIR methodology and requirements for UN ECE and EMEP. Using the GIS system of CORINAIR the gridded data for EMEP can be directly extracted from the CORINAIR database. Presently also a better harmonization with the IPCC methodology is being developed for the reporting of greenhouse gas emissions.

Speciations of NMVOC emissions are not planned yet. To enable better usage of the inventory in modelling (photo-chemical) air pollution problems (summer smog) this information however is needed.

In the near future it is foreseen to compile emission inventories as well as projections for future years for the European countries using a (modified) CORINAIR methodology once every year. By doing so time series and trends can be evaluated and analysed. This will greatly enable the use of CORINAIR in policy studies. This will also facilitate the use of the CORINAIR databases in Environmental Outlook studies, using a scenario approach.

7. References

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8. Glossary of terms and abbreviations

Aeq Acid equivalents: a measure of the emissions of acidifying pollutants. The emission in Aeq's is expressed as follows[1]:
{Aeq} = 0.0313* {SO_2 }+ 0.0217 * {NO_x } + 0.0588 * {NH_3}

Ceq Carbon dioxide equivalents. The emission in Ceq's is expressed as follows
{Ceq} = 1 * {CO} + 24.5 * {CH_4} + 320 * {N_2O}
The emision of CFC's should also be included, but is neglected in this report because no data are available within CORINAIR.

CFCs chlorofluorocarbons

CH_4 Methane

CO Carbon monoxide

CO_2 Carbon dioxide

CORINAIR COoRdination d'INformation Environmentale

EEA European Environment Agency

EMAP Co-operative programme for Monitoring and Evaluation of the Long range Transmission of Air Pollutants in Europe

Gg gigagram = 10^9 gram = 1000 tons

GHGs greenhouse gases

GNP Gross National Product

HCFCs hydro chlorofluorocarbons

IPCC Intergovernmental Panel on Climate Change

LRTAP convention on Long Range Transboundary Air Pollution

mln million

N_2O Nitrous oxide

NAPFUE Nomenclature for Air Pollution of Fuels

NH_3 Ammonia

NMVOC Non Methane Volatile Organic Compounds

NO_x Nitrogen oxides

POPs persistent organic pollutants

SNAP Selected Nomenclature for Air Pollution

SO_2 Sulphur dioxide

Tg teragram = 10^{12} gram = million tons

UN/ECE United Nations Economic Commission for Europe

[1] {..} brackets are used to indicate "expressed as ..."

Appendix

Per capita emissions per country in 1990 (kg/inhabitant)

COUNTRY (population mln)	SO_2	NO_x	NMVOC	NH_3	N_2O	CO_2	CO	CH_4
Germany (former West)	15	40	41	9.0	2.9	11,600	118	80
Italy	39	36	44	6.6	2.5	8,500	179	68
United Kingdom	66	49	47	9.0	3.0	10,200	117	59
France	23	28	51	12.5	4.0	8,600	195	54
Spain	56	32	48	8.4	5.1	7,300	126	76
Netherlands	14	39	31	13.8	1.7	10,700	74	70
Portugal	27	21	61	8.8	5.2	5,400	103	37
Greece	64	54	71	46.8	20.4	8,100	114	547
Belgium	33	36	41	8.2	2.7	10,800	127	39
Denmark	39	53	35	24.6	3.2	10,900	154	148
Ireland	50	33	55	35.5	12.7	8,900	121	239
Luxembourg	39	63	56	20.4	1.9	30,700	468	67
Sweden	12	41	86	8.8	3.9	20,300	160	250
Austria	12	30	86	12.3	1.1	7,000	223	113
Switzerland	7	25	45	10.7	1.9	7,500	106	53
Finland	46	54	92	8.2	6.4	11,500	91	199
Norway	13	55	64	9.0	3.7	8,200	225	67
Malta	16	31	12	14.7	0.2	5,900	62	24
Poland	85	38	34	15.1	4.0	10,800	193	159
Romania	56	23	33	12.9	4.6	7,400	137	84
Germany (former East)	262	34	51	11.7	2.2	18,300	202	71
Hungary	86	18	14	5.8	2.0	5,800	73	58
Czech Republic	181	75	28	8.8	6.0	15,300	101	151
Bulgaria	224	40	44	36.0	5.4	10,100	100	66
Slovakia	102	43	45	12.5	4.2	9,500	94	61
Lithuania	59	42	31	22.4	3.3	9,200	139	76
Latvia	43	35	38	14.2	3.5	6,900	138	278
Slovenia	98	28	17	13.5	5.8	6,300	38	62
Estonia	175	46	32	18.4	2.8	18,900	221	105
European average	58	37	45	11.8	3.9	9,900	145	94
Croatia	38	18	45	9.4	4.5	5,082	139	67

SNAP level 2 definitions

SNAP subsector	Description
0101	PUBLIC POWER AND COGENERATION PLANTS
0102	DISTRICT HEATING PLANTS
0301	INDUS. COMBUS. IN BOILERS, GAS TURBINES AND STATION. ENGINES
0302	INDUSTRIAL COMBUSTION - PROCESS FURNACES WITHOUT CONTACT
0303	INDUSTRIAL COMBUSTION - PROCESSES WITH CONTACT
0401	PRODUCTION PROCESSES - PETROLEUM INDUSTRIES
0402	PRODUCTION PROC. - IRON AND STEEL INDUSTRIES AND COLLIERIES
0403	PRODUCTION PROC. - NON FERROUS METAL INDUSTRY
0404	PRODUCTION PROC. - INORGANIC CHEMICAL INDUSTRY
0405	PRODUCTION PROC. - ORGANIC CHEMICAL INDUSTRY
0406	PRODUCTION PROC. - WOOD,PAPER PULP,FOOD,DRINK & OTHER IND.
0407	PRODUCTION PROC. - COOLING PLANTS
0501	EXTRACTION AND 1ST TREATMENT OF SOLID FUELS
0502	EXTRACTION, 1ST TREATMENT AND LOADING OF LIQUID FUELS
0503	EXTRACTION, 1ST TREATMENT AND LOADING OF GASEOUS FUELS
0504	LIQUID FUEL DISTRIBUTION (except gasoline)
0505	GASOLINE DISTRIBUTION
0506	GAS DISTRIBUTION NETWORKS
0601	SOLVENT USE - PAINT APPLICATION
0602	SOLVENT USE - DEGREASING AND DRY CLEANING
0603	SOLVENT USE - CHEMICALS PRODUCTS MANUFACTURING OR PROCESSING
0604	SOLVENT USE - OTHER USE OF SOLVENTS AND RELATED ACTIVITIES
0701	ROAD TRANSPORT - PASSENGER CARS
0702	ROAD TRANSPORT - LIGHT DUTY VEHICLES < 3.5 t
0703	ROAD TRANSPORT - HEAVY DUTY VEHICLES > 3.5 t AND BUSES
0704	ROAD TRANSPORT - MOPEDS AND MOTORCYCLES < 50 CM3
0705	ROAD TRANSPORT - MOTORCYCLES > 50 CM3
0706	ROAD TRANSPORT - GASOLINE EVAPORATION FROM VEHICLES
0801	OTHER MOB. SOURCES - OFF ROAD VEHICLES AND MACHINES
0802	OTHER MOB. SOURCES - RAILWAYS
0803	OTHER MOB. SOURCES - INLAND WATERWAYS
0804	OTHER MOB. SOURCES - MARINE ACTIVITIES
0805	OTHER MOB. SOURCES - AIRPORTS (LTO cycles and ground act.)
0901	WASTE TREATMENT AND DISPOSAL - WASTE WATER TREATMENT
0902	WASTE TREATMENT AND DISPOSAL - WASTE INCINERATION
0903	WASTE TREATMENT AND DISPOSAL - SLUDGE SPREADING
0904	WASTE TREATMENT AND DISPOSAL - LAND FILLING
0905	WASTE TREATMENT AND DISPOSAL - COMPOST PRODUCTION FROM WASTE
0906	WASTE TREATMENT AND DISPOSAL - BIOGAS PRODUCTION
0907	W.T.D. - OPEN BURNING OF AGRICULTURAL WASTES (except 10.03)
0908	WASTE TREATMENT AND DISPOSAL - LATRINES
1001	AGRICULTURE - CULTURES WITH FERTILIZERS except animal manure
1002	AGRICULTURE - CULTURES WITHOUT FERTILIZERS
1003	AGRICULTURE - STUBBLE BURNING
1004	AGRICULTURE - ANIMAL BREEDING (enteric fermentation)
1005	AGRICULTURE - ANIMAL BREEDING (excretions)
1101	NATURE - DECIDUOUS FORESTS
1102	NATURE - CONIFEROUS FORESTS
1103	NATURE - FOREST FIRES
1104	NATURE - NATURAL GRASSLAND
1105	NATURE - HUMID ZONES
1106	NATURE - WATERS
1107	NATURE - ANIMALS
1108	NATURE - VOLCANOES
1109	NATURE - NEAR SURFACE DEPOSITS
1110	NATURE - HUMANS

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