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EMISSION OF SO_2, NO_x, VOC and NH_3 IN THE NETHERLANDS AND EUROPE IN THE PERIOD 1950 - 2030

The Emission Module in the Dutch Acidification Simulation Model

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUMMARY

In this report the emission module of the Dutch Acidification Simulation (DAS) Model is described. The DAS-Model has been developed by the National Institute for Public Health and Environmental Protection (RIVM), Bilthoven, The Netherlands, together with a number of other research institutes.
Both the structure of the emission module and the data base are presented in this report. The data base contains data on the emission of NO_x, SO_2, NH_3, and VOC (Volatile Organic Compounds).
The emission data cover the period 1950-1985 for The Netherlands (20 regions) and part of Europe (13 regions). Also scenarios for emissions in the future (up to 2030) are presented.

SAMENVATTING

In dit rapport wordt de emissie-module van het Nederlandse Verzuringsmodel (DAS) beschreven. Het DAS-model is ontwikkeld door het Rijksinstituut voor Volkgezondheid en Milieuhygiëne (RIVM) te Bilthoven, in samenwerking met een aantal andere onderzoeksinstellingen.

In het rapport wordt een beschrijving gegeven van de structuur van de emissie-module en de gebruikte gegevens. Het gaat hierbij om gegevens over de emissie van NO_x, SO_2, NH_3, en VOS (Vluchtige Organische Stoffen).

De emissie-gegevens hebben betrekking op de periode 1950 - 1985 voor Nederland (20 gebieden) en een gedeelte van Europa (13 gebieden). Ook worden scenario's gepresenteerd voor de emissie van genoemde stoffen in de toekomst (tot 2030).

1. INTRODUCTION

Within the framework of the Dutch Priority Programme on Acidification the Dutch Acidification Simulation model (DAS) has been developed under the project leadership of the National Institute for Public Health and Environmental Protection (RIVM). The DAS-model contains a mathematical description of the complete chain from the emission of acidifying compounds to the impacts on the environment. The model consists of several modules, dealing with: emission, atmospheric distribution and deposition, soil, terrestrial ecosystems, aquatic ecosystems, agricultural production, and damage to materials (cf. Schneider and Bresser, 1988). In Figure 1.0 a scheme of the DAS model is given.

The study consists of three parts: the development of a demonstration model, the definition of the final model and the realisation of this final model. This report deals with the third stage of the development of the emission module.

Several institutions have participated in the construction of the emission module: the Agricultural University (Wageningen), the University of Utrecht, the Energy Study Centre (Petten), and The Netherlands Organization for Applied Scientific Research (Delft).

After a general chapter concerning the structure of the module, data on emissions of the four acidifying substances (SO_2, NO_x, NH_3 and VOC (=Volatile Organic Compounds)) in 1980 and in 1985 are presented in Chapter 3. These data refer to 20 regions in The Netherlands and 13 regions abroad. The emission areas are shown in Figures 1.1 and 1.2 .

Chapter 4 deals with the emissions in the period 1950 - 1975.

In Chapter 5 scenarios for The Netherlands are discussed. The scenarios used are in accordance with the national economy/energy-scenarios as developed by the Central Planning Bureau (CPB,1986).

In chapter 6 scenarios for the foreign emission areas are described.

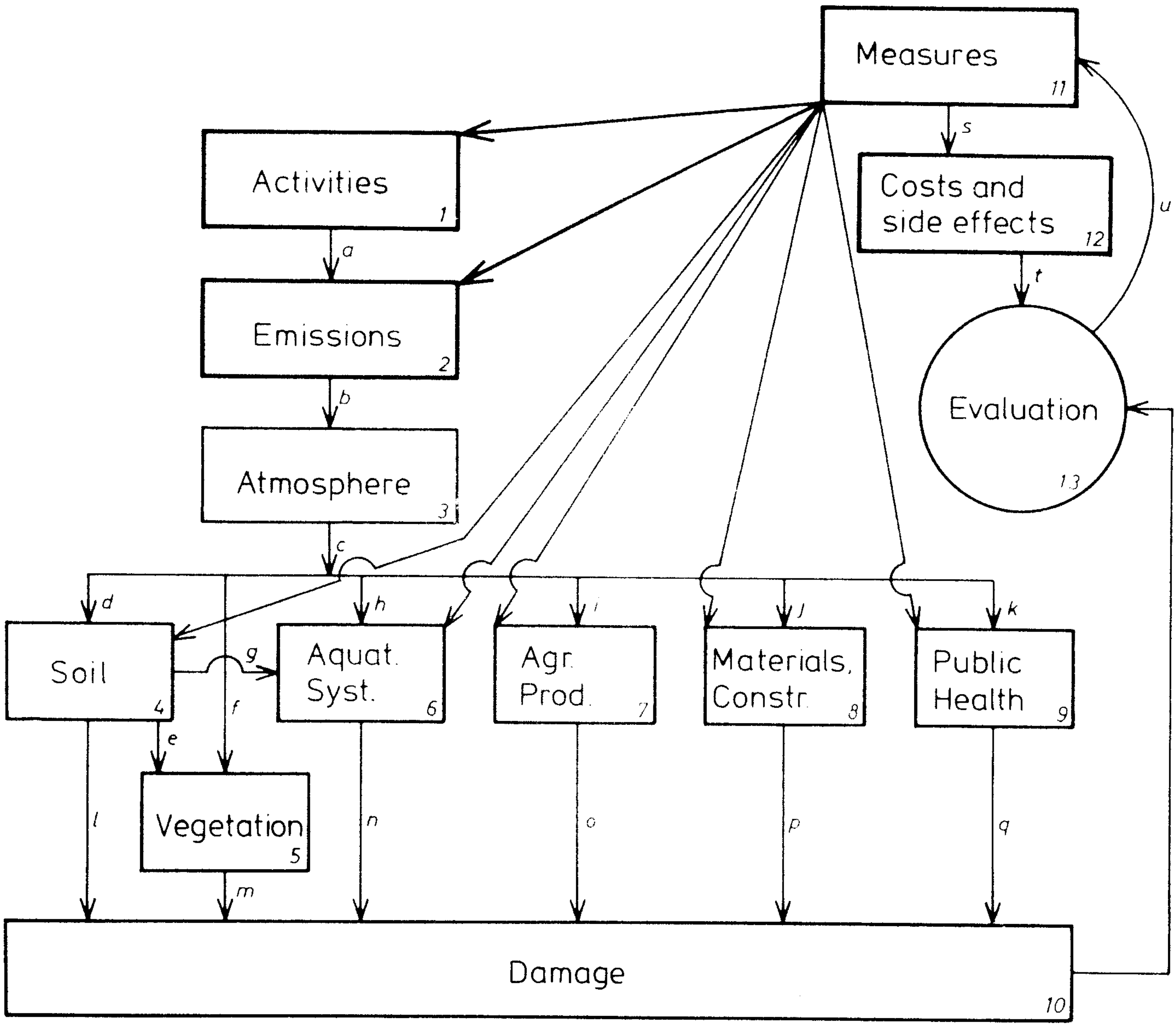


Figure 1.0. Scheme of the DAS model

Figure 1.1. The 20 Dutch emission areas in DAS.

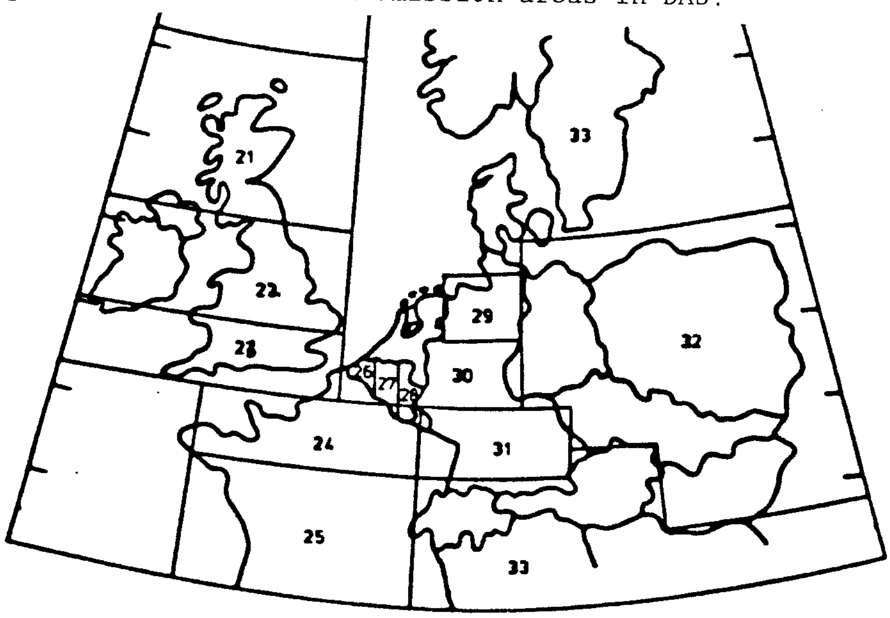


Figure 1.2. The 13 foreign emission areas in DAS.

Region 32 = GDR, Poland, Czechoslovakia and Hungary.
Region 33 = Norway, Sweden, Finland, Denmark, Switzerland, Austria, Italy, Spain, Portugal, and European USSR.

2. STRUCTURE OF THE EMISSION MODULE

2.1. Introduction.

The emission module has to generate data on the emission of SO_2, NO_x, NH_3, and VOC per sector for the years 1950 - 2030, both for The Netherlands and for the other European DAS-areas. It should also be possible to apply abatement techniques, resulting in lower emissions.
The emission data have to be generated not only on a national level, but also distributed over the 33 DAS-areas (cf. Figures 1.1. and 1.2.). Also the stack height of the emission sources has to be known, since transport through the air is dependent on the source height.

Within RIVM, a model is available that generates this type of information for The Netherlands on a national scale: RIM (Reken- en Informatiesysteem Milieuhygiene; Information and Accounting System of the Environment). Therefore, RIM is used to calculate the Dutch emissions for the period 1985 - 2030. For the four neighbouring countries EMAC, a model constructed by the Agricultural University of Wageningen is used (cf Chapter 6).
For the period 1950 - 1985 a data base described in Chapter 4 is used. Desaggregation of the national emissions to regional emissions is performed by a submodel LOCAT.
In the next paragraphs, RIM and LOCAT are described. The structure of the emission module is shown in Figure 2.0.

2.2. RIM

RIM is a large model, although its structure is simple (Kok et al., 1988). The complexity is caused by the large number of data. For a large number of economic activities data are available on:

- type of activity causing emission: e.g. use of oil products, number of cows, amount of steel produced;
- extent of the activity in physical units;
- emission factors for all relevant compounds;
- abatement techniques, including their effect;
- cost of abatement techniques.

The emissions and costs of abatement can be calculated per sector, compound, and year.

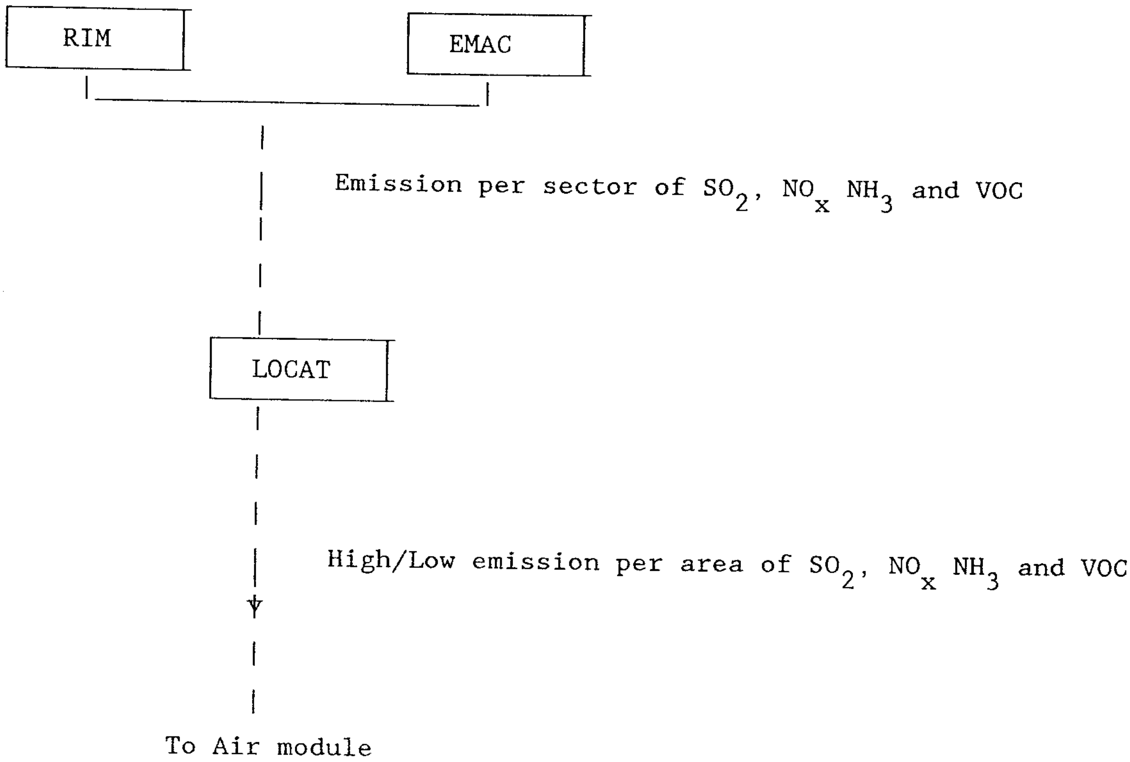


Figure 2.0. Structure of the Emission Module of the DAS-model.

2.3. LOCAT

According to the requirements of the Air Module the submodule LOCAT desaggregates the data derived from RIM and EMAC, viz.:

- according to the stack height of the emissions: below and above 50 meter;
- according to the emissions by sector in each area.

With respect to the height of the emissions the following procedure is applied:

Emissions of SO_2 and NO_x from the following sectors are assumed to be emitted above 50 m:

- refineries
- power plants
- primary metal industry
- chemical industry
- fertilizer industry
- food industry
- paper industry

Other sectors are assumed to be emitting at levels below 50 m.

NH_3 and VOC from all sectors are assumed to be emitted at levels below 50 m.

The regional distribution of emissions is accomplished in the following way:

From data supplied by TNO (Dutch Emission Inventory System) the distribution of the SO_2- and NO_x-emissions by each sector over the 20 Dutch areas in 1980 is known. These values have been scaled to a percentual emission of a sector in an area. This regional distribution of emissions per sector in 1980 (distribution matrix) is applied to the other years in the period 1950 - 2030. When a distribution matrix would become available for another year, it is possible to apply these data to the year concerned. It is assumed, that a distribution matrix is valid until the year that another matrix is available. From that year on, the new matrix is used in the model.

3. EMISSIONS IN 1980 AND 1985

3.1. Anthropogenic emissions in The Netherlands

3.1.1. Emission in 1980.

Information on the amount of SO_2 and NO_x emitted in 1980 in The Netherlands has been derived from several national sources, like CBS, VROM, and TNO. (Table 3.0.). The emission data from these sources differ to some extent, but the differences are small. More detailed information are given in Annex A, Tables A.1, A.2). The regional distribution of the emission of SO_2 and NO_x is based on data from the Dutch Emission Inventory System (Tangena et al, 1985) (Table A.3, A.4,).
In the Tables A.5 - A.7 the regional emission of SO_2 and NO_x based on the data from Table 3.0., A.3 and A.4 are presented.

Table 3.0. Emission of SO_2 and NO_x in 1980 in The Netherlands (kton).

SECTOR	EMISSION	
	SO_2	NO_x
Power plants	195	80
Refineries	121	19
Chemical industry	53	42
Other sectors	43	38
Domestic/services	14	34
Road traffic	15	277
Other traffic	22	59
Total	463	549

In order to be able to calculate the concentration in the air and the deposition of acidifying compounds, information is needed on the height of the emission in each region. The regional distribution of the emission of SO_2 and NO_x from low and high sources is shown in the Tables A.8 and A.9.

The anthropogenic emission of VOC in 1980 was 525 kiloton (Table 3.1) (VROM, CBS, TNO). The regional distribution of the VOC-emission has not been established, since that information is not used by the Air Module. All VOC are emitted from low sources.

Table 3.1. Emission of VOC in The Netherlands in 1980 (kton).

SOURCE		EMISSION
Traffic	Passenger cars	159
	Trucks/buses	46
	Motorcycles	15
	Other mobile sources	9
Combustion	All sources	28[#]
Industry	Chemical industry	38
	Storage and handling	19
	Refineries	15
	Metal products industry	34
	Printing industry	13
	Other industry	12
Small industry	Painting and decorating	38
	Car repair	8
	Gasoline stations	10
	Laundries	3
	Other industry	24
Domestic solvent use		31
Agriculture	Manure	10
	Pesticides	14
Total		525

[#] including methane emission (appr. 15 kiloton)

In 1980, 250 kiloton NH_3 was emitted in The Netherlands. Table 3.2. shows how much was emitted by the various sources (derived from VROM, 1987). Because other emission factors have been used, the emission from domestic animals is appr. 60 % higher than the emissions reported by Buijsman (Buijsman et al, 1984). The regional distribution of the NH_3-emission (Table A.10) has been derived from Buijsman et al. (1986) (Table A.11).

Table 3.2. Emission of NH_3 in The Netherlands in 1980 (kiloton).

SOURCE		EMISSION
Manure	Cattle	140
	Pigs	51
	Poultry	28
Fertilizer use		9
Industry		8
Other sources	Domestic	9
	Sheep	4
Total		250

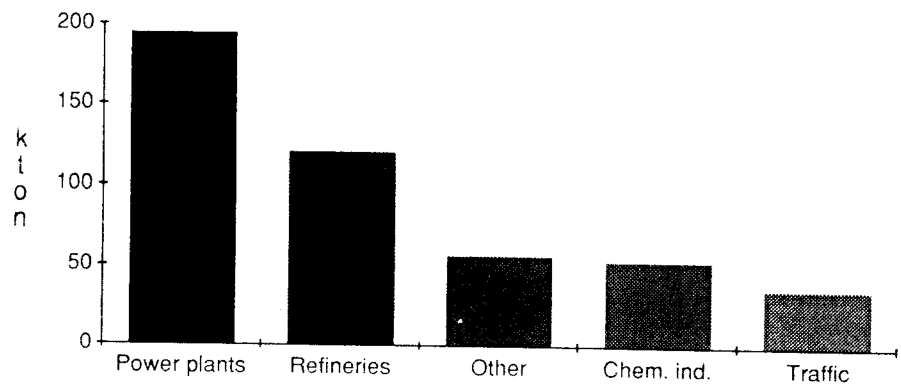


Figure 3.0. SO_2-emission in The Netherlands (1980)

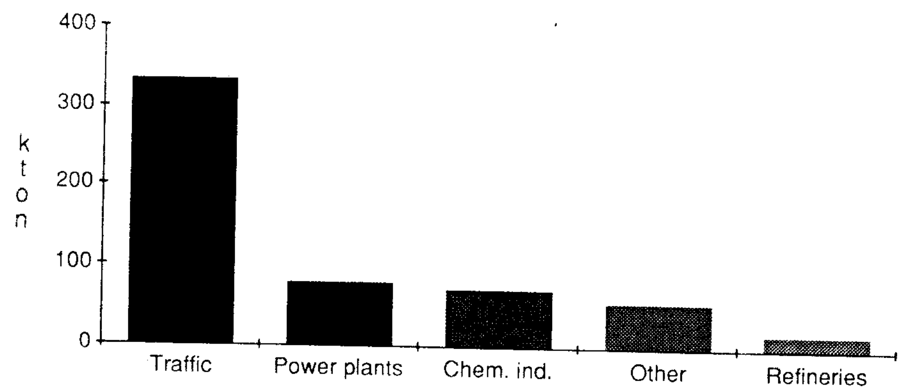


Figure 3.1. NO_x-emission in The Netherlands (1980)

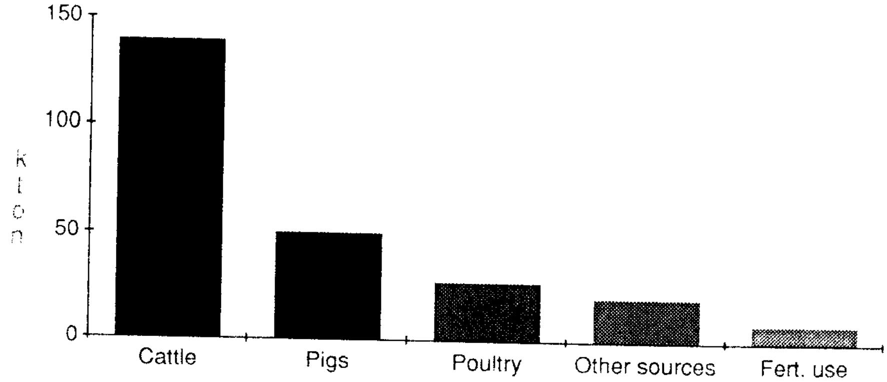


Figure 3.2. NH_3-emission in The Netherlands (1980)

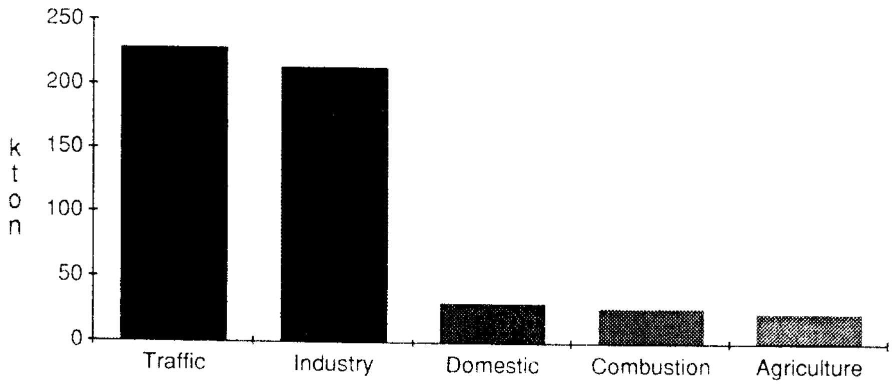


Figure 3.3. VOC-emission in The Netherlands (1980)

3.1.2. Emission in 1985.

Information on the emission of SO_2, NO_x, NH_3 and VOC in 1985 in The Netherlands has been derived from several sources (CBS, 1987a,b; VROM, 1987b); the data are shown in the Tables 3.3., 3.4., and 3.5.

Table 3.3. Emission of SO_2 and NO_x in The Netherlands in 1985 (kiloton).

SECTOR	EMISSION SO_2	EMISSION NO_x
Power plants	65	82
Refineries	95	17
Chemical industry	36	42
Other sources	47	72
Road traffic	11	272
Other traffic	21	59
Total	276	544

Table 3.4. Emission of NH_3 in The Netherlands in 1985 (kiloton).

SOURCE		EMISSION
Manure	Cattle	133
	Pigs	67
	Poultry	29
Fertilizer use		9
Industry		7
Other sources	Domestic	9
	Sheep	4
Total		258

Table 3.5. Emission of VOC in The Netherlands in 1985 (kiloton).

	SOURCE	EMISSION
Traffic	Passenger cars	138
	Trucks/buses	42
	Motorcycles	14
	Other mobile sources	10
Combustion		29[#]
Industry	Chemical industry	28
	Storage and handling	19
	Refineries	15
	Metal products industry	34
	Printing industry	12
	Other industry	11
Small industry	Painting and decorating	32
	Car repair	11
	Gasoline stations	10
	Laundries	3
	Other industry	20
Domestic solvent use		32
Agriculture	Manure	10
	Pesticides	14
Total		483

[#] including methane emission (appr. 15 kiloton)

3.2. Anthropogenic emission in the other countries.

Data on the emission of SO_2 and NO_x in 1980 and 1985 have been derived from sources like ECE (1987), OECD (1988), EMEP(1987), PHOXA (1987), and IIASA (1987).

Data on VOC-emissions in 1980 have been derived from a study by TNO (Baars, 1987), from Veldt (1987), and from OECD (1988). Data for 1985 are not yet available for most countries.

The data on the emission of NH_3 in 1980 have been derived from Buijsman et al. (1986a). The NH_3 emission data were raised by 40 -50 % in order to be consistent with the most recent emission data for The Netherlands (cf. 3.1). For NH_3 no emission data for 1985 have been reported yet.

In Table 3.6. and 3.7. the emission data of all four compounds are presented.

Table 3.6. Anthropogenic emission of SO_2, NO_x, VOC, and NH_3 in 1980 in the other countries (kiloton).

COUNTRY	SO_2	NO_x	VOC	NH_3
Belgium	799	442	313	129
France/Luxembourg	3581	1880	1983	1025
Fed. Republ. Germany	3200	3100	2471	575
Ireland	219	67	77	8
United Kingdom	4670	1916	1675	765
REGION 32:	12833	2744	2240	1632
German Dem. Republ.	4000	300	580	287
Czechoslovakia	3100	1204	370	244
Hungary	1633	400	350*	181
Poland	4100	840	940	921
REGION 33:	22242	6722	8452	3395
Austria	354	216	251	110
Denmark	438	251	173	156
Finland	584	280	161	67
Italy	3800	1480	1566	510
Norway	141	215	139	52
Portugal	266	166	159	70
Spain	3250	800	791	340
Sweden	483	328	422	87
Switzerland	126	196	310	79
USSR	12800	2790	4480*	1925

*Estimate

Table 3.7. Anthropogenic emission of SO_2, NO_x, VOC, and NH_3 in 1985 in the other countries (kiloton).

COUNTRY	SO_2	NO_x	VOC@	NH_3*
Belgium	500	390	310	129
France/Luxembourg	1858	1715	1160	1025
Fed. Republ. Germany	2400	2900	1800	575
Ireland	138	68	80	8
United Kingdom	3540	1837	1770	765
REGION 32:	12870	2540	2130	1632
German Dem. Republ.	4000	300	550	287
Czechoslovakia	3150	1100	350	244
Hungary	1420	300	330	181
Poland	4300	840	900	921
REGION 33:	18233	7259	8510	3395
Austria	170	216	250	110
Denmark	326	238	170	156
Finland	370	248	160	67
Italy	2250	1750	1600	510
Norway	100	215	140	52
Portugal	300	192	160	70
Spain	3250	951	790	340
Sweden	272	305	420	87
Switzerland	95	214	320	79
USSR	11100	2930	4480	1925

@Mainly 1980 data   *1980-data

3.3. Emissions from natural sources.

It is assumed that the emissions from natural sources did not change in the period 1950 - 1985 and will remain constant in the period 1985 - 2030.

3.3.1. NO_x-emissions.

NO_x-emissions from natural sources are relatively small. The main sources are soil, lightning, and oxidation of ammonia. In The Netherlands the emission is appr. 10 kiloton.year^{-1} (Van den Hout, 1985). In the Federal Republic of Germany appr. 58 kiloton NO_x is emitted per year (Sartorius, 1984). No information has been obtained for other countries.

Using the data on the emission in The Netherlands and in the FRG the emission in the other regions therefore has been estimated on basis of their surface area (Table A.12) (average NO_x-emission 0,23 $ton.km^{-2}.year^{-1}$).

3.3.2. SO_2-emissions.

The emission of SO_2 from natural sources is small and has therefore been neglected.

3.3.3. NH_3-emissions.

Information about non-anthropogenic emission of NH_3 is hardly available. According to Buijsman (1986a) the emission in EMEP-Europe is appr. 750 $kiloton.year^{-1}$ ($10\ \mu g.m^{-2}.h^{-1} \approx 0.09\ ton.km^{-2}.year^{-1}$). The emission in the DAS-area is then appr. 660 $kiloton.year^{-1}$ (Table A.13).

3.3.4. VOC-emissions.

In nature, VOC are mainly emitted by trees. Minor sources are grass land and swamps. The VOC emission by trees depends on temperature and light intensity. For The Netherlands the annual emission of VOC per km^2 decidious forest and coniferous forest is 1.2 and 6.4 ton respectively. The forest areas are resp. 1360 and 1960 km^2, so the total emission in The Netherlands is appr. 14 $kiloton.year^{-1}$ (Baars, 1987). In Table A.14 the equivalent data for some other European countries are shown; this Table also contains OECD-data and some estimates.

4. HISTORICAL EMISSIONS 1950 - 1975.

4.1. Introduction

The data on historical emissions will be used to estimate the accumulation of acidifying substances in the Dutch environment over the last decades.
In this chapter an inventory of the emissions in the past is presented. Depending on the sensitivity of the DAS-model for these data the uncertainty of the data will perhaps have to be reduced, although this will not be easy.
The emission data are presented in 5-year intervals for the period 1950-1975, including the assumptions which have been made to obtain these data.

4.2. The Netherlands.

4.2.1. SO_2- and NO_x-emissions

In the Tables 4.0 and 4.1 and the Figures 4.0 and 4.1 data on the emissions of SO_2 and NO_x from 1950 to 1975 are presented; the emissions from industry (excluding the sector "small industry") and power plants are considered to be 'high' emissions and the remainder 'low emissions'. It is assumed, that the regional distribution of emissions in the period 1950-1975 has been the same as in 1980.
The data for 1960-1975 are derived from reports on emissions from stationary combustion sources and traffic (CBS, 1975, 1982a, 1984a). The data on process emissions are also derived from the Central Bureau of Statistics (CBS, 1982b) and from the Dutch Emission Inventory (TNO, 1985). It is assumed, that the process emissions before 1980 are a fixed percentage of the combustion emissions from industrial sources (base year: 1980). Comparison of the results for 1970 with other references (Stapel, 1975; Jansen et al, 1978) indicates that due to this assumption the process emissions are overestimated.
The data for the years before 1960 are derived from the energy consumption as published by CBS (CBS, 1962).
In Figure 4.2 the relation between emission from high and low sources in the period 1960 - 1975 is shown. Based on this graph the following assumptions are made:

- the decrease of the fraction 'low' NO_x, which is observed for the period 1960 to 1975 (due to increasing contribution of traffic emissions), has started in 1950.

- the fraction 'high' SO_2-emissions in the period 1950-1960 has been the same as in 1960.

In the Tables A15 - A18 (Annex) the SO_2- and NO_x emissions (high and low) in the 20 Dutch regions as derived from the Tables 4.0., 4.1., A.3 and A.4 are shown.

Table 4.0. Emission of SO_2 in The Netherlands in the period 1950 - 1975 (kiloton.year^{-1}).)

	1950*	1955*	1960	1965	1970	1975
agriculture			40	64	60	10
refineries			126	120	150	148
fertilizer industry					5	1
other chem. industry					26	22
chemical industry			49	72		
primary metal industry			21	40	28	2
other large industry			111	124	69	11
small industry			72	90	58	16
power plants			130	190	130	32
district heating			0	0	0	0
domestic			108	175	132	58
passenger cars/vans			1	2	3	4
lorries/buses			9	13	11	10
shipping			6	8	10	14
other traffic			1	1	2	1
process emissions**			141	167	125	78
TOTAL	510	680	814	1066	810	415
high emissions***	360	480	578	713	533	302
low emissions***	150	200	236	354	276	112

* derived from energy consumption
** fixed percentage of industrial emissions
*** division high/low as in 1960

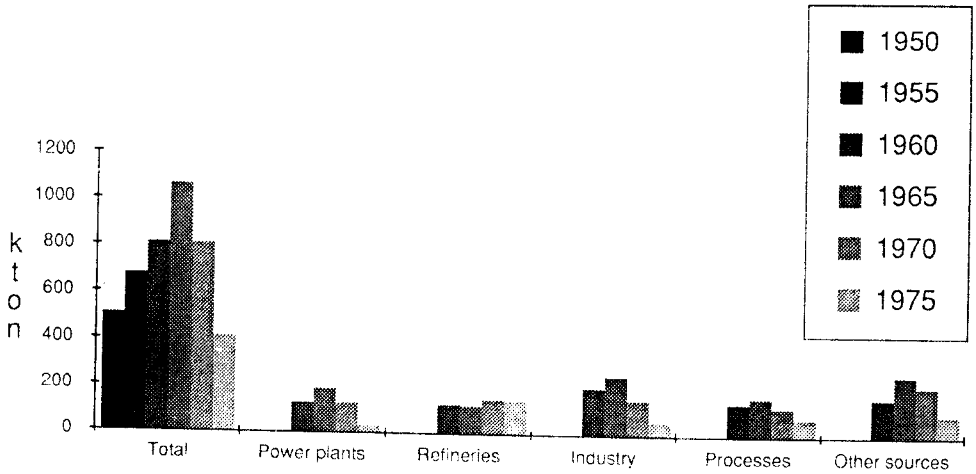


Figure 4.0. SO_2-emission in The Netherlands (1950 - 1975).

Table 4.1. Emission of NO_x in the period 1950 - 1975 in The Netherlands (kiloton.year^{-1}).

	1950*	1955*	1960	1965	1970	1975
agriculture			4	7	10	6
refineries			13	14	25	30
fertilizer ind.						5
other chem. ind.						20
chemical industry			9	12	19	
primary met. ind.			6	10	10	4
other lrg. ind.			20	21	17	6
small industry			11	13	13	10
power plants			62	72	66	59
distr. heating			0	0	0	0
domestic			18	28	38	35
pass. cars/vans			20	42	78	98
lorries/buses			37	50	54	59
shipping			21	30	38	45
other traffic			6	7	7	3
process emissions**			24	28	34	30
TOTAL	175	215	250	333	410	410
high emissions ***	115	125	134	157	172	153
low emissions ***	60	90	117	176	238	257

* derived from energy consumption
** fixed percentage of industrial emissions (basis: 1980)

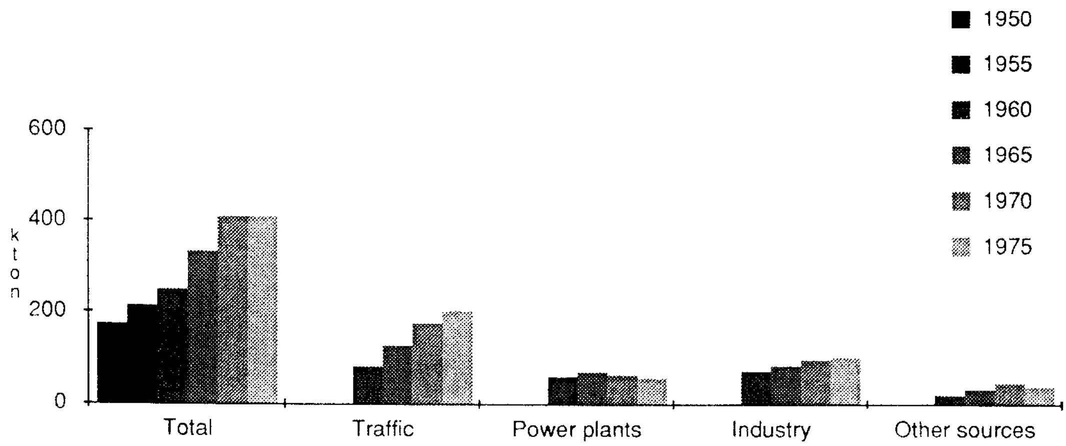


Figure 4.1. NO_x-emission in The Netherlands (1950 - 1975).

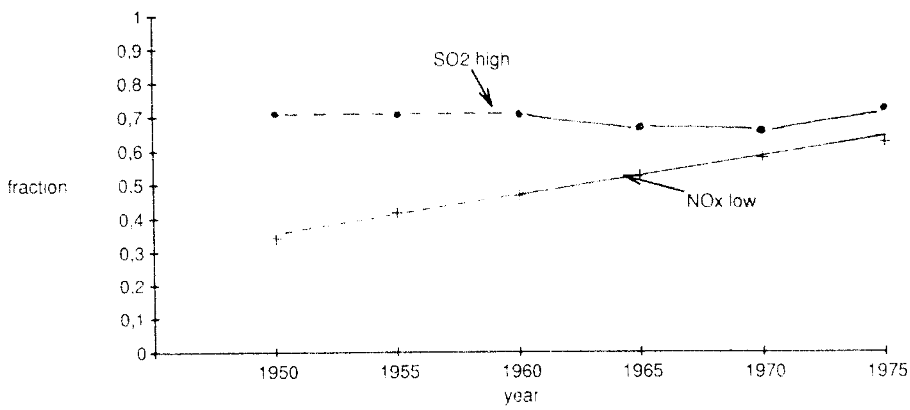


Figure 4.2. Fraction of emission of SO_2 and NO_x from high resp. low sources in The Netherlands (1950 - 1975).

4.2.2. Ammonia emissions.

Data on ammonia emissions in the period 1950-1975 for the source domestic animals and fertilizers have been derived from Buijsman et al (1986b). The data on emission by domestic animals are based on statistical data of livestock numbers as published by CBS. Livestock numbers for all Dutch municipalities were used. Animal categories considered are: cattle, pigs, and poultry. Also statistics which showed a detailed sub division within these animal categories were used.
Since the 1980-emission data reported by Buijsman are appr. 60 % lower than emission data reported recently (cf. 3.1.2.), the emission data for the period 1950 - 1975 are also increased in order to be consistent with the 1980 emission data.
The ammonia emission from fertilizers has been calculated using several N-consumption fertilizer reports. For each year an average emission factor, derived from the emission factors for individual N-fertilizers (Buijsman et al., 1986a), and data on the relative use of different N-fertilizers in that specific year were used. The average emission factor was, for all years considered, 2.3 % of the amount of fertilizer-N used.
The emission of ammonia by inhabitants, cats, dogs, and sheep has been calculated using data on the number of these sources and emission factors, as derived from the emission in 1980. The emission by industry has been derived from Buijsman (1986c).
The resulting data on ammonia emissions in the 20 Dutch areas in the period 1950-1975 are shown in the Tables A.19 - A.24 (Annex) and in Figure 4.3.

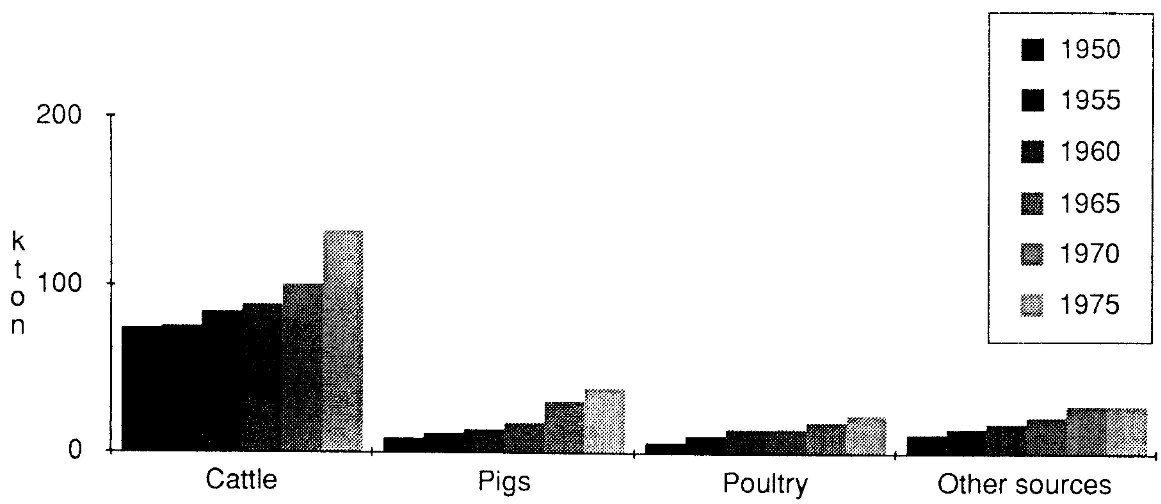


Figure 4.3. NH_3-emission in The Netherlands (1950 - 1975)

4.2.3. VOC emissions.

Data on the emission of VOC due to solvent use, industrial processes, and gasoline distribution, have been reported by Baars (Baars, 1987). The data on emission due to the use of fossil fuels in mobile and stationary sources have been obtained from CBS or have been or derived from data on energy use (CBS). In Table 4.2. and Figure 4.4 the results are shown.

Table 4.2. Emission of VOC in The Netherlands in the period 1950 - 1975, (kiloton, anthropogenic sources).

YEAR	Process emission	Solvent evaporation	Gasoline distribution	Traffic	Energy use	TOTAL
1950	29	50	3	39	92	213
1955	87	64	4	63	85	303
1960	140	79	6	82	75	382
1965	209	98	9	133	60	509
1970	144	138	13	143	26	464
1975	76	159	14	131	20	400

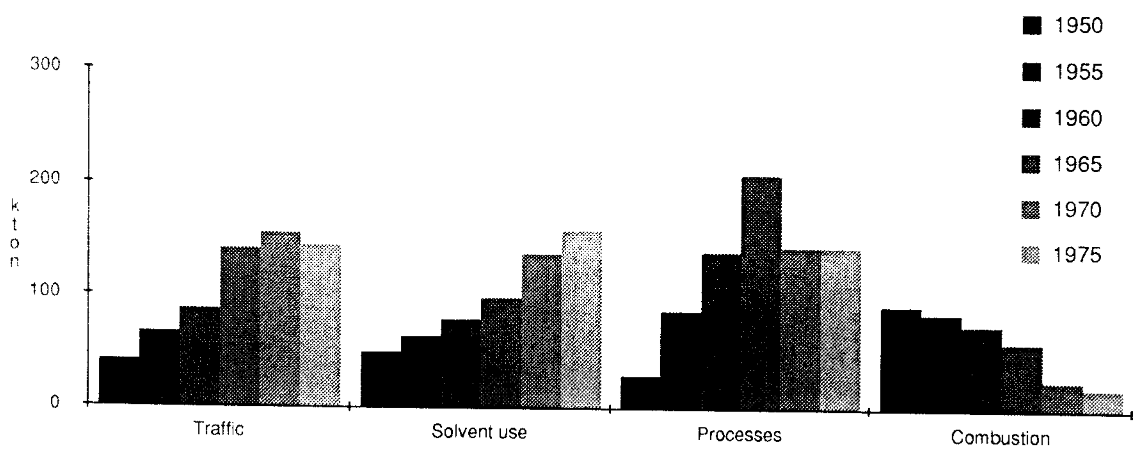


Figure 4.4. VOC-emission in The Netherlands (1950 - 1975)

4.3. Other countries

4.3.1. SO_2- and NO_x-emissions

From other references little information on emissions in the past is available. Most 'data' therefore had to be calculated from data on energy use in the period concerned. The results are shown in Table 4.3. and 4.4. In the Annex it is explained, how these data have been calculated (A.25).

4.3.2. Ammonia emissions

Estimates of the ammonia emissions for most European countries in the period 1950-1975 have been presented by Buijsman (1986c). The results include emissions by different animal types as well as by fertilizers; the ammonia emission due to coal combustion has been estimated only very roughly.
The ammonia emission factors used by Buijsman (1986c) were derived from Buijsman et al. (1986a) and again a correction has been applied in order to make the emission data for the period 1950 - 1975 consistent with the data for 1980 (cf. 3.2.).
The resulting data on ammonia emissions in the regions 21 - 33 are presented in the Tables 4.5 and A.26.

4.3.3. VOC-emissions.

Data on VOC-emissions due to solvent use and industrial processes in 14 of the 20 foreign DAS-countries have been reported by Baars (1987). Data on these types of emission in the remaining 6 countries have been estimated using data on population). The emission due to combustion of fossil fuels (stationary and mobile sources) has been estimated using data on energy use or has been derived from sources like OECD (1988) and PHOXA (1987). In Table A.25 an explanation is given; the results are shown in Table 4.6.

Table 4.3. SO_2-emissions in the other countries in the period 1950 - 1975 (kiloton).

Region	Country	1950	1955	1960	1965	1970	1975
	Ireland	97	116	110	149	222	190
	United Kingdom	4357	5043	5348	6010	6090	5130
21		646	748	791	893	915	771
22	(incl. Ireland)	2476	2869	3035	3424	3510	2958
23		1332	1543	1632	1841	1887	1591
	France/Luxemb.	1258	1361	1568	2179	3046	3282
24		805	871	1004	1395	1949	2100
25		453	490	565	785	1097	1182
	Belgium	456	568	595	750	965	845
26		150	188	196	248	318	279
27		210	261	274	345	444	389
28		96	119	125	158	203	177
	FRG	1662	2349	2642	3200	3600	3600
29		266	376	423	512	576	576
30		948	1339	1506	1824	2052	2052
31		449	634	713	864	972	972
32		4595	6591	8140	9951	11200	11595
	Czechoslowakia	1349	1786	2297	2901	3276	3012
	GDR	1413	2039	2321	2677	2940	2987
	Hungary	524	969	1215	1617	1665	1597
	Poland	1309	1797	2307	2755	3318	3999
33		4967	7682	9985	13557	18181	20705
	Austria	119	192	206	297	407	413
	Denmark	144	202	274	393	527	426
	Finland	44	85	118	400	515	535
	Italy	290	516	863	1738	3020	3093
	Norway	70	111	134	172	281	147
	Portugal	39	48	64	91	116	178
	Spain	376	543	645	1062	1836	3004
	Sweden	227	368	532	713	930	690
	Switzerland	21	32	50	92	137	122
	USSR (Europe)	3637	5586	7099	8598	10411	12097
ALL REGIONS		17392	23710	28388	35796	43304	45347

Table 4.4. NO_x-emissions in the other countries in the period 1950 - 1975 (kiloton).

Region	Country	1950	1955	1960	1965	1970	1975
	Ireland	38	42	39	45	62	58
	United Kingdom	1799	2024	1983	2056	2033	1758
21		176	198	194	202	201	174
22	(incl. Ireland)	1044	1174	1149	1193	1190	1032
23		617	694	679	706	704	610
	France/Luxemb.	827	949	1081	1379	1365	1647
24		544	623	710	906	897	1082
25		284	325	371	473	468	565
	Belgium	346	409	391	425	497	437
26		80	94	90	98	114	100
27		187	221	211	230	268	236
28		80	94	90	98	114	100
	FRG	1061	1527	1794	2000	2400	2700
29		223	321	377	420	504	567
30		456	657	771	860	1032	1161
31		382	550	646	720	864	972
32		1048	1475	1869	2288	2578	2549
	Czechoslowakia	543	719	933	1145	1283	1141
	GDR	109	157	178	203	218	221
	Hungary	124	228	283	375	389	363
	Poland	271	371	475	565	688	824
33		1458	2129	2723	3778	5217	5886
	Austria	90	125	130	162	199	200
	Denmark	78	97	107	155	219	203
	Finland	36	60	77	132	206	216
	Italy	188	309	459	814	1358	1425
	Norway	30	40	46	58	90	84
	Portugal	19	19	24	34	72	104
	Spain	130	166	188	256	385	624
	Sweden	107	141	178	226	302	310
	Switzerland	52	68	96	148	208	186
	USSR (Europe)	729	1104	1419	1793	2177	2534
ALL REGIONS		6577	8555	9880	11971	14151	15035

Table 4.5. NH_3-emissions in the regions 21 - 33 in the period 1950 - 1975 (kiloton).

REGION	1950	1955	1960	1965	1970	1975
21	68	68	73	81	85	103
22	320	320	346	382	399	487
23	134	134	145	160	167	204
24	272	304	307	343	395	470
25	299	335	337	377	435	517
26	25	26	29	30	34	39
27	35	36	40	42	48	55
28	10	10	11	12	14	16
29	145	145	153	167	178	194
30	107	107	113	123	132	144
31	193	192	204	222	237	258
32	772	792	869	946	1040	1308
33	2056	2031	2360	2517	2740	3223

Table 4.6. VOC-emission in the regions 21 - 33 in the period 1950 - 1975 (kiloton).

YEAR	BELGIUM	FRANCE LUXEMB.	FRG	UK + IRELAND	REGION 32	REGION 33
EMISSION FROM ALL SOURCES:						
1950	129	1346	694	704	1397	6404
1955	180	1568	889	908	1733	7707
1960	222	1866	1150	1215	1976	9258
1965	310	2342	1617	1500	2287	11501
1970	439	3166	1971	2055	2863	12013
1975	359	2995	2029	1793	3262	12889
EMISSION FROM NATURAL SOURCES:						
1950-1975	35	1004	220	88	752	5404
EMISSION FROM ANTHROPOGENIC SOURCES:						
1950	94	342	474	616	645	1000
1955	145	564	669	820	981	2303
1960	187	862	930	1127	1224	3854
1965	275	1338	1397	1412	1535	6097
1970	404	2162	1751	1967	2111	6609
1975	324	1991	1809	1705	2510	7485

5. EMISSION SCENARIOS FOR THE NETHERLANDS (1980-2030).

5.1. Introduction.

Essentially each scenario, which is consistent with the data requirements of DAS, can be implemented in the DAS-emission module. This implies that the contents of the emission module will change in the future. When more recent or more detailed scenarios become available, they can be added to DAS. The scenarios described in this chapter and also in chapter 6 are the scenarios that were available in april 1988.

5.2. Emission of SO_2 and NO_x due to combustion

5.2.1. Introduction.

The emission of SO_2 and NO_x due to combustion in the Netherlands in the years 2000, 2010 and 2030 has been estimated by the Energy Study Centre (ESC) by means of the SELPE-model. SELPE is a model that provides projections of future energy use and supply due to a given energy demand. This demand can be derived from scenarios about future economic and technical developments. In SELPE it is also possible to define the use of abatement technologies according to environmental policy. The main results of these studies are data about the emissions of SO_2 and NO_x, and about the costs of energy supply and emission abatement.

In this chapter the results of the scenario studies published by the Dutch Central Planning Bureau (CPB, 1986a) are used. The Energy Study Centre has defined starting points for the energy policy until 2010 as published in connection with the NEV-study (Bruggink et al, 1987). Projections are also made for the year 2030, using basic data from the NEV-study to forecast the economic development and the intensity of energy use.

Future emissions depend on the amount and type of energy used, but also on the level of abatement. Three abatement scenarios will be distinguished: a scenario based on abatement according to directives published by VROM (1985) and two scenarios resulting in lower emissions due to the application of more abatement.

5.2.2. International economic development.

The Central Planning Bureau has published three scenarios (CPB, 1986a). In the so called "HIGH" variant, a substantial growth of the world trade is assumed; the growth will be lower after the year 2000. In the "LOW" scenario a stagnating growth is assumed until the year 2000, whereafter a recovery will begin. The growth in de "MIDDLE" variant is low in comparison to that assumed in the "HIGH" scenario.
The assumed international economic developments are shown in Table 5.0.

Table 5.0. Economic starting points for the scenarios according to CPB.

	Index 1985/ 1980	1985 - 2000 growth per year (%)			2000 - 2010		
		H	M	L	H	M	L
Worldtrade	111	6.50	4.00	1.25	5.25	4.00	3.00
Price:							
Energy	145	7.25	3.25	-1.00	6.25	6.00	3.50
Raw materials	118	4.75	2.50	0.25	4.75	4.00	1.50
Industrial products	142	4.50	2.50	0.75	5.25	4.25	2.25

5.2.3. The Dutch economy until 2010

Due to the open character of the Dutch economy its development is strongly affected by world trade. This is the main reason for the differences in the basic data for the economic scenarios in the period until 2010 (Table 5.1) (CBS, 1985; CPB, 1986b).

Table 5.1. Main data for economic scenarios in the period 1985 - 2010.

	1985 (1980=100)	1985 - 2000 yearly growth (%)			2000 - 2010		
		H	M	L	H	M	L
Volume of:							
Private consumption	98	4.50	3.50	1.75	4.75	2.75	2.50
Export	117	6.25	4.25	1.50	4.25	3.25	2.25
Industrial production	105	4.50	3.50	1.50	3.25	2.50	2.00
Gross national product	105	4.00	3.00	1.25	3.00	2.25	2.75
Price of private consumpt.	121	4.25	2.00	0.75	5.75	4.50	2.75

Economic growth is an important variable for the price of crude oil. Estimations for energy prices are given in Table 5.2. For 2030 it is assumed that prices of energy carriers are relatively the same as in 2010.

Table 5.2. Energy prices in the period 1980 - 2030.

		Price		Indices			
		1980	1985	1980	1985	2000	2010
Crude oil# (Dfl/bl)		50	96	100	100	112	133
Natural gas@ (high consumption)	Dfl/m^3	0.25	0.47	100	153	112	127
Natural gas@ (low consumption)	Dfl/m^3	0.33	0.56	100	138	144	163

\# Deflated with the international price of industrial products (Dfl.).
@ Deflated with the price of inland consumption.

Due to the differences in energy intensity between the different sectors, detailed information about the volume of the gross production per sector is needed in order to estimate the energy demand. In Table 5.3 the percentages of growth and indices for the gross production per sector are given.
The indices of 1985 are calculated from data published by TNO (Gerritse et al, 1986), and CBS (Nederlandse Energiehuishouding, several years). CPB (1986a) has made assumptions on the production per sector for the years 2000 and 2010. The production per sector for the year 2030 is estimated by statistical extrapolation of the "LOW" growth production indices between 1980 and 2010. The resulting increase of production is also used for the approximation of the production in the "HIGH" variant.

CPB has published data about the expected intensity in the future, especially for the years 2000 and 2010. The Energy Study Centre has estimated the development of energy intensities in the period 2010 - 2030.
The main assumption for these estimations was that the intensity will continue to decrease but not as fast as in the period 2000 - 2010.
The efficiency indices for the use of energy are presented in Table 5.4.

Table 5.3. Volume of gross production per sector. (1980 = 100)

Sector	1985	2000 H	2000 M	2000 L	2010 H	2010 M	2010 L	2030 1) H	2030 1) L
Agriculture	130	234	203	151	313	260	181	355	235
Fertilizer industry	124	193	155	134	247	180	147	250	170
Petrochemical industry	124	193	155	134	247	180	147	250	170
Other chemical industry	124	310	234	151	518	360	213	600	290
Iron and steel industry:									
ferrous	107	193	193	134	299	258	172	340	220
non-ferrous	107	54	54	54	54	54	54	54	54
Other metal industry	107	295	257	180	504	398	266	620	380
Food industry	106	206	173	123	268	211	145	300	175
Textile industry	101	210	157	94	256	201	115	270	125
Paper industry	105	252	203	142	338	260	176	385	215
Other industry	100	240	193	135	322	247	167	375	200
Construction	91	132	114	91	186	139	113	201	122
Public services	104	202	177	140	285	227	169	350	220
Private sector 2)	112	134	132	128	142	139	134	152	145
Transport 3)	107	156	142	123	201	171	143	210	175

1) Estimations by ESC
2) Houses
3) Cars

Table 5.4. Efficiency indices for the use of energy in different sectors (1980 = 100).

Sector	1985	2000 H	2000 M	2000 L	2010 H	2010 M	2010 L	2030 1) H	2030 1) L
Agriculture	52	26	29	35	20	24	31	20	25
Fertilizer industry	86	65	71	80	58	65	74	52	65
Petrochemical industry	69	65	67	68	62	64	66	59	59
Other chemical industry	69	53	58	66	43	49	58	39	49
Iron and steel industry	79	51	62	72	40	52	70	38	62
Other metal industry	62	39	44	60	28	35	56	25	45
Food industry	88	63	69	77	47	53	62	45	56
Textile industry	88	61	66	83	48	53	73	47	66
Paper industry	88	55	61	71	40	46	57	38	49
Other industry	88	65	73	84	50	59	77	43	65
Construction	69	65	65	65	62	62	62	60	60
Public services	96	48	61	71	46	54	66	37	56
Private sector 2)	85	64	65	68	63	64	65	60	63
Transport 3)	94	71	74	78	70	71	76	66	72

1) ESC estimates
2) Houses
3) Private cars

Since power generation is an important source of emissions, it is also important to know the future electricity demand. The Central Planning Bureau has published data about the supposed development of the intensity of the use of electricity in the period until 2010. These data have been used by ESC to estimate these intensities in the period 2010 - 2030.
The main idea is that in the "HIGH" (production) scenario the indices for the use of electricity will decrease, but not as fast as in the period 2000 - 2010. In the "LOW" (production) scenario an intensity is used equal to the mean values of the sectoral data for the period 2000 - 2010.
The indices used are shown in Table 5.5.

Table 5.5. Efficiency indices for the use of electricity (1980 = 100).

Sector	1985	2000		2010		2030 1)	
		H	L	H	L	H	L
Agriculture	77	69	72	63	69	57	66
Fertilizer ind.	76	52	49	52	49	51	51
Petrochemical ind.	121	86	87	78	89	77	85
Other chemical ind.	121	86	95	81	95	77	86
Iron and steel ind.	75	35	44	25	35	20	34
Other metal ind.	82	77	81	71	79	64	78
Food industry	90	83	86	76	82	68	81
Textile industry	90	74	72	70	79	66	83
Paper industry	90	82	88	77	84	70	86
Other industry	90	80	88	74	84	67	83
Construction	100	91	100	82	100	80	100
Public services	100	94	97	88	97	83	94
Private sector 2)	115	69	69	63	63	60	60

1) ESC estimates
2) Houses

Knowing the demand for energy the required energy supply system can be determined using the SELPE model.

5.2.4. Energy Supply System.

For these calculations the energy model SELPE is used. This model has been developed at the Energy Study Centre and minimizes the total cost of the Dutch energy supply system on basis of the energy demand and several limiting conditions. In relation to the national energy study (Bruggink et al, 1987) a set of scenarios has been used. The main energy data of these scenarios are shown in the Tables 5.6 and 5.7. Three scenarios are distinguished:

- NUCLEAR-variant in which nuclear power plants are built, and at least 1/3 of the electricity can be produced by coal power plants.
- COAL-variant with only a few nuclear power plants till 2010.
- GAS-variant with gas as the main energy source for the production of electricity.

The CPB-scenarios concern the period till 2010, For the period 2010 - 2030 only scenarios for the COAL-variant have been developed.
It is supposed that in 2030 more electricity is produced by wind power than in 2010 due to production at the sea (2000 MW). Gasification of coal is not expected; preliminary calculations show that producting electricity by means of integrated coal gasification will reduce the emission of SO_2 and NO_x by approximately 4 %.

The data on use of energy, as shown in Table 5.6, consist of energy used for combustion and energy used for other applications (e.g. production of plastics and fertilizers). For determining the emissions of SO_2 and NO_x the energy used for combustion only must be known (Table 5.7).

Table 5.6. Use of energy in 2000, 2010, and 2030 (PJ) (Bruggink et al, 1987).

Scenario	Growth	2000	2010	2030
Gas	High	3269	3855	
	Low	2634	2882	
Coal	High	3329	3975	4099
	Low	2649	2911	3312
Nuclear	High	3377	4107	
	Low	2666	2991	

Table 5.7. Energy use for combustion in different scenarios (PJ) (ESC).

Scenario			Coal	Oil	Gas	Other	Total
Gas	High	2000	351	501	1660	6	2518
		2010	456	585	1850	10	2901
	Low	2000	309	443	1314	7	2073
		2010	345	481	1430	9	2265
Coal	High	2000	720	501	1351	7	2579
		2010	1033	585	1394	9	3021
		2030	1105	582	1405	11	3103
	Low	2000	390	443	1247	8	2088
		2010	474	481	1330	9	2294
		2030	571	541	1455	12	2579
Nuclear	High	2000	523	501	1331	7	2362
		2010	470	585	1333	9	2397
	Low	2000	311	443	1250	7	2011
		2010	246	481	1238	9	1974

5.2.5. Emission abatement policy.

In 1985 directives (AMvB) have been published on limits for the emission of NO_x and SO_2 due to combustion (VROM, 1985). These limits are used in the model and if necessary an abatement technology is defined.
The future emission factors (ton/PJ input) are based on the shares of new and old installations in each year; three types of installations are distinguished:
- installations built before 1986;
- installations in use before 1988;
- installations built after 1986.

An extended description of abatement technology, including data on costs and specific control etc., has been published by Van Arkel (1986).

5.2.6. Results.

The emission in 2000, 2010, and 2030 based on the AMvB directives (cf 5.2.5.) are calculated by the SELPE model. The results are shown in Table 5.8 as

A(batement)**1**. In the same Table it is shown how much NO_x and SO_2 will be emitted if no abatement is applied ("**UA**").

Abatement policies, that also imply more expensive techniques result in lower emissions. In Table 5.8 ("**A2**" and "**A3**") it is shown, how much SO_2 and NO_x will be emitted when such techniques are also applied (Bruggink et al., 1987, Van Arkel, 1988).

In the DAS-model emissions have to be known per sector per area. The calculated total emissions per sector are attributed to the DAS-areas on basis of the distribution of the emission in 1980 (cf. Annex, A.4 and A.5). For the future this distribution may be influenced by changes in the location of the various sources, especially power plants. Based on assumptions and knowledge on the future locations of power plants the future distribution-matrix for the emission of NO_x and SO_2 has been reported (Van Arkel, 1988a).

Table 5.8. Emissions of SO_2 and NO_x in the different scenarios (kiloton).

			Emission*							
			SO_2				NO_x			
Scenario			UA	A1	A2	A3	UA	A1	A2	A3
Gas	High	2000	582	202	111	107	691	545	395	344
		2010	656	246	152	148	867	616	408	332
	Low	2000	526	181	110	106	561	466	320	255
		2010	499	199	110	106	640	466	320	255
Coal	High	2000	932	259	136	132	729	553	398	328
		2010	1205	336	192	187	923	635	411	313
		2030	1316	346	196	191	939	643	425	314
	Low	2000	601	193	103	100	569	452	334	284
		2010	624	218	117	113	650	472	324	252
		2030	791	237	127	122	742	535	374	287
Nuclear	High	2000	734	233	133	128	670	521	385	326
		2010	654	259	173	168	750	542	375	299
	Low	2000	524	183	101	97	546	441	330	284
		2010	399	190	114	110	567	424	302	241

*incl. process emissions.

5.3. Emission of SO_2 and NO_x due to processes

The future emission of SO_2 and NO_x due to industrial processes, is also a function of economic development and control strategies. Scenarios for these emissions are hardly available.

5.3.1. SO_2 process emissions

The emission of SO_2 by refineries (Claus plants), due to the production of coke, and due to the burning of domestic waste is included in the SELPE results (Table 5.8.). The estimates for the emission by other industrial sources have been adapted from Olsthoorn and Thomas (1986), and from the report on the evaluation of the acidification policy (VROM, 1987b). In Table 5.9 the data applied in the DAS-emission module are shown.

Table 5.9. SO_2-process emissions in the Netherlands, 1980 - 2030 (kiloton).

SECTOR	1980	2000		2010/2030	
		A	E	A	E
Chemical industry:					
sulphuric acid	20	2	1	3	1.5
silicon carbide	5	0.5	0.5	0.5	0.5
carbon black	3.4	3.5	0.7	3.5	0.7
activated carbon	0.7	0.5	0.5	0.5	0.5
other chemicals	3	3.5	3.2	3.5	3.2
Primary metal industry:					
iron and steel	5.5	8	2	8	2
aluminum	3.9	3.1	2	3.1	2
lead	0.4	0.4	0.4	0.4	0.4
Building materials industry:					
mineral wool	1.7	0.3	0.3	0.3	0.3
glass	0.9	1	0.2	1	0.2
bricks/stoneware	0.6	0.1	0.1	0.1	0.1
other building materials	0.3	0.2	0.2	0.2	0.2
TOTAL	46	23	11	24	12

A = Autonomous development; E = Extra abatement applied

5.3.2. NO_x process emissions

The concepts presented below are adapted from Olsthoorn and Thomas (1986). The major part of the NO_x- process emissions is due to the production of fertilizers (ammonia - and nitric acid plants) (Table 5.10).
It is to be expected, that the emission from ammonia plants will diminish drastically, because the process-gas (that contains NH_3, which is burnt to

NO_x), will be cleaned. The emission due to the production of caprolactam, ammonium nitrite, and nitric acid plants will also be lower in the future, because plants are modernised.

Table 5.10. NO_x-process emission in the Netherlands, 1980 - 2030 (kiloton).

PROCESS	1980	2000/2010 A	2000/2010 E
Nitric acid	14.6	7	3
Ammonia	1.6	0	0
Caprolactam	1.7	0.5	0.5
Ammonium nitrite	4	0.4	0.4
Activated carbon	0.1	0.1	0.1
TOTAL	22	8	4

A = Autonomous development; E = Extra abatement applied

5.4. Emission of ammonia.

5.4.1. Emission from manure.

The emission of ammonia from manure depends on:

- number of cows, pigs, poultry, and calves
- stable types
- amount of manure applied
- application method of manure
- N-content of food (and manure) of cattle
- methods for processing excess manure

A projection of the future ammonia emission due to cattle can be obtained from several models, viz. a model constructed by the Institute for Environmental Studies (IvM) (Kuik, 1987, 1988), the National Eutrophication Model - NEM - (RPC,1987), the RIM-model (Kok, 1988), and a model developed by the Agricultural Economic Institute (LEI) (Oudendag and Wijnands, 1988). In the DAS-model the results from calculations with the NEM-model are used (Koster et al, 1988). In Table 5.11 the results are shown; the values of the parameters mentioned above are presented in the Annex (Table A.28).

Table 5.11. Emission of NH_3 (kiloton) from manure in 2000 and 2010/2030 in The Netherlands.

Source	2000	2010/2030	
	A#	A	E
Stable	52	52	22
Soil	95	84	6
Total	147	136	28

#A = Autonomous development E = Extra abatement applied.

5.4.2. Emission of NH_3 from other sources

It is assumed, that the emission of ammonia from other sources (humans, domestic animals, fertilizer, and industry) does not change much in the future (Table 5.12)

Table 5.12. Emission of ammonia in the Netherlands from other sources (1980 - 2030).

Source	1980	2000	2010/2030
Humans/pets/sheep/horses	13	13	13
Fertilizer	9	10	13
Industry	8	4	4
Fertilizer industry	3.5	1.5	1.5
Chemical industry	1.5	0.4	0.5
Other industry	2.6	1.8	2
Total	30	27	27

5.5. Emission of VOC.

5.5.1. Introduction.

As was shown in section 3.1. most VOC is emitted by mobile sources. Other important sources are industry and households. In the following sections emission scenarios for these three sources will be discussed in more detail. At this moment scenarios for 2010 are available for traffic only, for 2030 no scenarios have been reported at all. For the time being in DAS the emission in the period 2010 - 2030 is assumed to remain constant.

5.5.2. Traffic related emissions

The emission of VOC due to traffic mainly depends on the number of vehicles and the extent to which they are used. Other parameters, which influence the emission are the type of fuel used and the way the emission of VOC from the exhaust and from the fuel tank + carburetor (evaporation of gasoline) is abated.
The estimation of the future extent of traffic and the related emission is the subject of many studies. For the period 1980 - 2010 data have been published by Bruggink et al (1987), NEI (1986, 1987), and Jansen et al (1987). In this report data derived from the last three studies, which have been calculated with the RIM-model are presented.

Passenger cars.

The number of passenger cars increases from 4.5 million in 1980 to appr. 7 million in 2010 (depending on the economic development) (Table 5.13). The share of cars using diesel or LPG and the amount of kilometers also increases (Table 5.14).

Table 5.13. Number of passenger cars in 1980, 1985, 2000 and 2010 in The Netherlands (million).

Fuel type	1980	1985	2000			2010		
			economic development					
			low	medium	high	low	medium	high
gasoline	3.8	3.8	5	5.7	5.4	5.6	6	6.2
diesel	0.2	0.3	0.3	0.4	0.8	0.5	0.6	0.8
LPG	0.3	0.5	0.4	0.6	0.9	0.6	0.7	0.8
Total	4.2	4.6	5.7	6.7	7.0	6.7	7.3	7.9

Table 5.14. Kilometers driven by passenger cars in 1980, 1985, 2000 and 2010 in the Netherlands (10^9 kilometers).

Fuel type	1980	1985	2000			2010		
			economic development					
			low	medium	high	low	medium	high
gasoline	49	47	58	69	65	67	73	82
diesel	4.2	9.5	7	11	17	11	16	18
LPG	7.7	12	10	14	20	14	17	19
Total	61	68	75	93	102	91	105	119

The VOC-emission depends on future emission standards. In Table 5.15 emission based on two sets of emission factors are presented:

a) factors based on moderate emission control (EG 15-05 standards),
b) factors based on stringent emission control (≈ US-83 standards).

The emission of VOC due to evaporation of gasoline from fuel tank and carburetor is appr. 18 kiloton in 1980/1985 and 25 kiloton in 2000/2010.

Other traffic

Most VOC is emitted by trucks and vans. Other sources are ships, aircrafts, and tractors. In Table 5.16 the emission data for 1980, 1985, 2000 and 2010 are shown. The data for the emission by vans and trucks have been calculated by the RIM-model, the emission by the other sources are estimates.

Table 5.15. Emission of VOC (kiloton) by passenger cars in 1980, 1985, 2000 and 2010 (combustion only, medium economic development).

Standards	1980	1985	2000	2010
EG 15-05	141	120	114	125
US-83	141	120	38	42

Table 5.16. Emission of VOC by other traffic in 1980, 1985, 2000 and 2010 (kiloton, medium economic development).

	1980	1985	2000	2010
Van	14	12	7	8
Truck	30	26	15	17
Other road traffic	18	18	15	15
Ships	3	3	3	3
Tractors	4	4	4	4
Aircrafts	1	1	1	1
Other traffic	1	1	1	1
Total	71	65	46	49

5.5.3. Industrial process emissions.

According to the Ministry of VROM (VROM, 1987b) the emission in 2000 will be approximately 147 kiloton (Table 5.17). It is assumed that the emission in 2010 will be approximately the same.

5.5.4. Emission due to domestic activities.

The most important domestic activities resulting in emission of VOC are painting, cleaning, and the use of aerosols (Table 5.18). The extent of emission in the future depends mainly on the amount of paint used, the VOC-content of paint and the use of aerosols in spray cans.
In the study by VROM (1987) it is assumed, that the emission will remain approximately constant in the period 1981 - 2000, viz. 31 kiloton in 1981 and 30 kiloton in 2000.

Table 5.17. Emission of VOC by industry (kiloton).

	1981	1985	2000/2010
Large Industry	130	118	83
Small industry	73	69	64
Gasoline stations	10	10	10
Total	213	197	147

Table 5.18. Emission of VOC due to domestic activities in 1980, 1985 and 2000 (kiloton).

	1981	1985	2000/2010
Paint	15	16	14
Cleaning/cosmetics	15.7	15.7	15.7
Total	31	32	30

5.5.5. Emission due to agriculture.

In the study by VROM (1987) a decrease of the emission of VOC due to agricultural activities is reported; the emission will be 19.5 kiloton in 2000 due to a decrease of the amount of manure. The accuracy of these data is low.

5.5.6. Summary of VOC-emission scenarios for the Netherlands.

The data on VOC-emissions in the Netherlands are summarized in Table 5.20.

Table 5.19. Emission of VOC due to agriculture in 1980, 1985 and 2000 (kiloton).

	1981	1985	2000
Manure	10	10	6.5
Pesticides	14	14	13
Total	24	24	19.5

Table 5.20. VOC-emission scenarios for the Netherlands (kiloton).

Sector	1985	2000		2010	
		Auton.	Abated	Auton.	Abated
Combustion:					
Passenger cars	120	114	38	125	42
Vans/trucks	38	21	18	25	21
Other traffic	27	24	24	24	24
Stationary sources#	29	25	25	25	25
Evaporation:					
Mobile sources	18	25	5	25	5
Industry	197	147	75	147	75
Domestic	32	29	15	29	15
Agriculture	24	19	19	19	19
TOTAL	485	404	220	419	226

#estimate; including methane

6. EMISSION SCENARIOS FOR THE OTHER COUNTRIES (1980 - 2030).

6.1. Introduction.

Scenarios for the future emission of SO_2 and NO_x in the period 1980 - 2030 in the neighbouring countries - Belgium, Federal Republic of Germany, France, and United Kingdom - are obtained from the EMAC-model (Van Ierland, 1988). For the period 1980 - 2000 the scenarios are based on the "Energy 2000 Study" (Guilmot et al, 1986), the assumptions for the period 2000 - 2030 are presented in this report.

The SO_2- and NO_x-emission data for the year 2000 for the other European countries (section 6.3.) are based on (national) statements on the emissions by the end of the century (ECE, 1987). Because no projections have been made for the period 2000 - 2030 it is assumed, that the changes in the amount of SO_2- and NO_x-emission in these countries are the same as in the four EMAC-countries. Emission scenarios for VOC- and NH_3-emissions for all foreign countries are presented in section 6.4. and 6.5.

6.2. Emission of SO_2 and NO_x in the neighbouring countries.

6.2.1. Emission due to combustion.

To calculate the combustion of SO_2 and NO_x for the neighbouring countries of the Netherlands the European Model for ACidification (EMAC-model) is applied. This model is developed by the Department of General Economics of the Agricultural University in Wageningen in commission of the Dutch Priority Programme on Acidification (Additioneel Programma Verzuringsonderzoek). The European model for acidification is described in detail in Van Ierland and Oskam (1987). The model distinguishes for each country 16 types of economic activity, including manufacturing, services and government, housing and transport, as well as electricity generation and refineries. The EMAC-model calculates for all activities the energy consumption per fuel type (solid fuel; oil and oil products; gas) and the use of electricity. On the basis of energy use per fuel type per activity the combustion emissions of SO_2 and NO_x are calculated, first assuming that no pollution abatement takes place as compared to the 1980 situation, secondly assuming specific abatement measures per type of activity for each pollutant for each fuel type. As the EMAC-model is developed to calculate long term emission scenarios for a wide range of assumptions about economic growth, energy efficiency improvement, fuel mix and abatement policies, a large number of exogenous variables is included in the model.

In section 6.2.2. the characteristics of the EMAC-model are described. The most important assumptions of the model calculations are summarised in section 6.2.3., in particular the assumptions on economic growth per type of activity; fuel mix per type of activity; energy efficiency improvement per type of activity per fuel type; and abatement policy per type of activity per fuel type. Section 6.2.4. deals with process emissions, and in section 6.2.5.the results are shown of the calculations for the period 1980-2030.

6.2.2. Some characteristics of the EMAC-model.

General characteristics.

The EMAC-model describes the relationships between economic activity, energy demand and supply, electricity generation, refineries and the emissions of sulphur dioxide and nitrogen oxides for a number of countries in North-West Europe, in particular: Western Germany, France, Belgium and the United Kingdom.
The general structure of the EMAC-model is as straightforward as possible in order to get a clear overview of the most important relations and parameters. Therefore, the model contains a large number of exogenous instrument variables that may be varied to analyse their impact on the projected emission levels. As a result the EMAC-model is able to simulate a large number of policy options with regard to economic growth per activity, energy efficiency improvement, fuel mix and abatement policy.

Classification of activities

In the EMAC-model a moderate level of aggregation is chosen in order to show the characteristics of each activity (i.e. energy intensity, fuel mix, pollution per unit of product), without getting too large a number of activities. The chosen classification of activities is shown in Table 6.0.
Activities 1-14 are indicated as 'non energy activities' as opposed to the 'energy activities' of the sectors electricity generation and refineries. The non energy sectors include four industrial sectors, i.e. basic industry, chemical industry, metal products industry and other industry. The sector construction is distinguished separately. As far as transport is concerned the model includes private cars (petrol and lpg), private cars (diesel), other road transport, railway traffic, water traffic and air traffic. Furthermore, the sector agriculture is distinguished and the activities of the services sector and government. Finally, the activities of households are included for stationary combustion and electricity consumption by households. The energy activities consist of the sectors 'electricity generation' and 'refineries'.

Table 6.0. Classification of activities in the EMAC-model

	Activity	EC-classification[1)]
1.	basic industry	13,15
2.	chemical industry	17
3.	metal products industry	24,28
4.	other industry	36,42,47,50
5.	construction	53
6.	private cars (petrol and LPG)	2)
7.	other road transport	,,
8.	railway traffic	,,
9.	water traffic (interior)	,,
10.	air traffic	,,
11.	agriculture	01
12.	services and government	68,86
13.	households/dwellings	2)
14.	private cars (diesel)	,,
15.	electricity generation	091
16.	refineries	030,050,070

1) Source:Eurostat, Regional Accounts, ESA, 1982.
2) Source:Eurostat, Yearbook of regional Statistics, 1985.

Main outline of the EMAC-model

The main outline of the model for non energy activities is given in Figure 6.0, which shows how the levels of economic activity in combination with the relevant energy coefficients provide the amount of energy use per type of activity. The energy use per type of fuel is calculated on the basis of the relevant fuel mix, whereafter the energy efficiency index (1980=1.00) is used to calculate the energy consumption after efficiency improvement. On basis of the emission factors per pollutant per type of activity per fuel type the emission levels before abatement are calculated. Finally using the abatement indices (specified for each pollutant per type of activity per fuel type) the emission of SO_2 and NO_x for all aggregated regions of the countries considered are calculated.

The main outline of the EMAC-model for the sectors electricity generation and refineries is given in Figure 6.1. It shows that the total national demand for electricity is calculated on the basis of electricity consumption per activity. Taking into account the trade balance of electricity and the characteristics of the electricity generation sector (for example fuel mix and loss factor) and the regional distribution of electricity generation, the emissions of SO_2 and NO_x are calculated for each aggregated region, assuming that no abatement takes place. Next the degree of pollution abatement is specified to calculate the emissions of SO_2 and NO_x after pollution abatement. The structure of the EMAC-model for refineries is equivalent to that for electricity generation.

Classification of regions

The regional classification of the EMAC-model is based on the EC regional classification level 1. Figure 6.2 shows the regional classification for the countries concerned. Table 6.1 shows how the EMAC-regions are aggregated to DAS-regions.

For the base year 1980 the regional distribution of activities is taken from published statistics (Eurostat,1985), although for the transport sector some additional assumptions had to be made because of the lack of suitable data. For the period 1990-2030 the regional distribution of activities is the result of the assumed annual rates of growth per activity and the percentage share of each region in the national total for each activity. In this study the rates of growth for all non-energy activities have been assumed to be the same for all regions in a country.

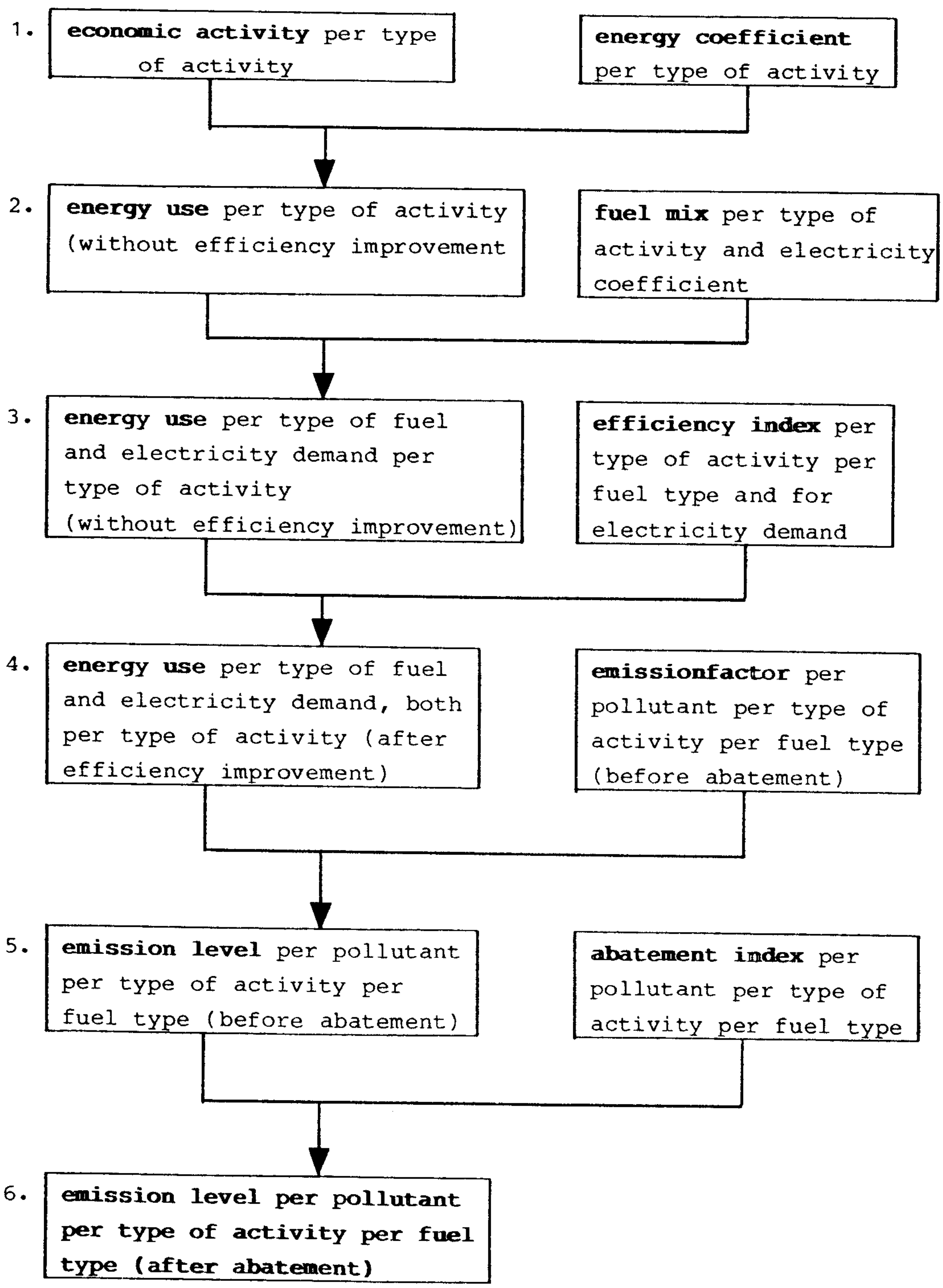


Figure 6.0. Main outline of the EMAC-model: relations per region for non-energy activities.

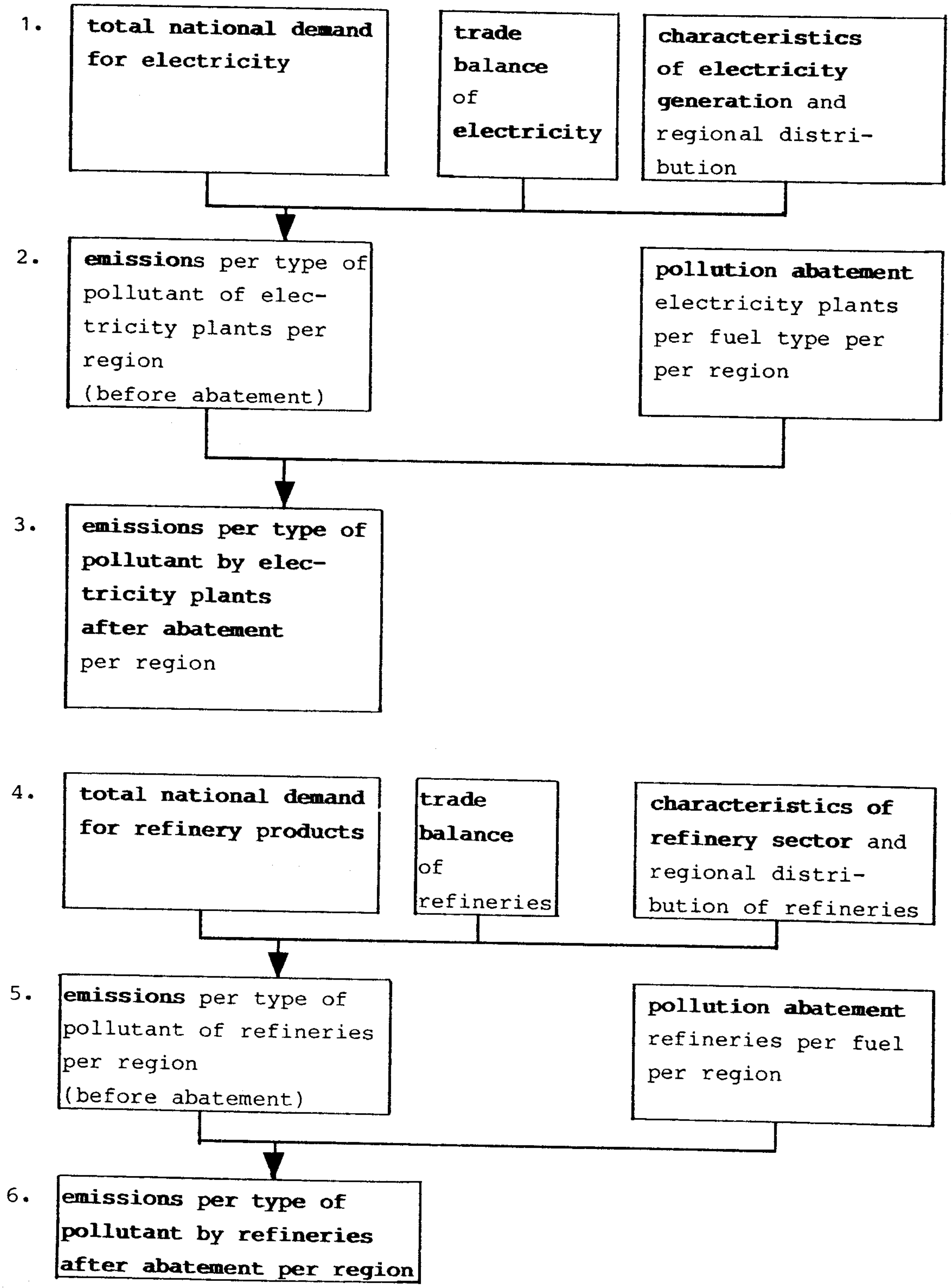


Figure 6.1. Main outline of the EMAC-model: relations per region for electricity generation and refineries.

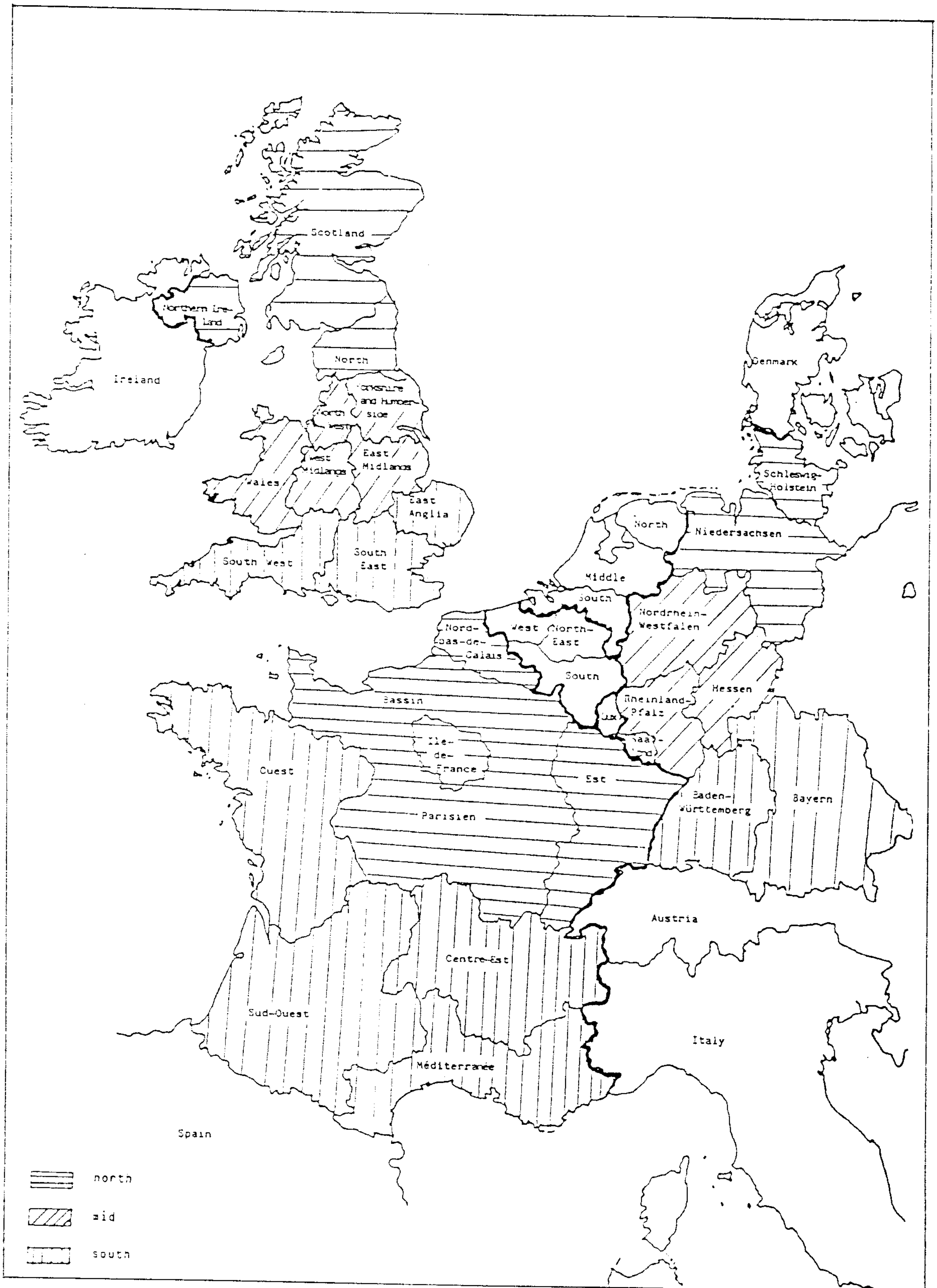


Figure 6.2. Regional classification of the EMAC-model.

Table 6.1. Regional classification of the EMAC-model.

Country	Aggregated EMAC-region	EC-regions and EMAC-regions
West Germany	W.Germany North	1 Schleswig-Holstein/Hamburg
		2 Niedersachsen/Bremen
	W.Germany Mid	3 Nordrhein-Westfalen
		4 Hessen
		5 Rheinland Pfalz
		6 Saarland
	W.Germany South	7 Baden-Wurtemberg
		8 Bayern
France	France North	1 Nord-Pas de Calais
		2 Ile de France
		3 Bassin Parisien
		4 Est
	France South	5 Ouest
		6 Sud Ouest
		7 Centre
		8 Mediterranee
United Kingdom	U.K. North	1 Scotland/Northern Ireland
		2 Northern
	U.K. Mid	3 Yorkshire/Humberside
		4 East Midlands
		5 West Midlands
		6 North West
		7 Wales
	U.K. South	8 East Anglia
		9 South East
		10 South West
Belgium	Belgium West	1 West Vlaanderen
		2 Oost Vlaanderen
	Belgium North East	3 Antwerpen
		4 Brabant
		5 Limburg
	Belgium South	6 Hainaut
		7 Namur
		8 Liege
		9 Luxembourg

6.2.3. Main assumptions

Economic growth.

The main assumptions on economic growth for the period 1980-2000 are based on the study Energy 2000 (Guilmot et al 1985). As the level of aggregation of the EMAC model is more detailed than the aggregation level of the study Energy 2000, additional assumptions had to be made about the annual rate of growth per activity. For the purpose of the Dutch Priority Programme on Acidification additional assumptions have been made on average annual rates of growth per type of activity in the period 2000-2030. For the period 2000-2010 the assumptions are based on the projections that were made by the Central Planning Bureau in the Netherlands for the Dutch Economy (CPB, 1986). To adapt the figures to the structure of the EMAC-model some additional assumptions were made. The resulting assumptions are shown in Table 6.2. Generally speaking the assumptions for the period 2010- 2030 show an extrapolation of modest economic growth for all activities.
For West Germany the average annual rate of growth of Gross Domestic Product (GDP) in the period 1980-1990 amounts to 1.8%. The rate of growth of energy intensive branches of industry is projected to be 1% per year, while metal products industry and other industry show an annual rate of growth of 1.7%. The growth of transport in this period is about 1.7% per year, whilst railway traffic is projected to grow at an annual rate of 2.9%. For the period 1990-2000 the average annual rate of growth of GDP is about 2.8%. Particularly the metal products industry and other industry grow faster than the overall average at an average annual rate of 3.2%. For the period 2000-2010 industrial growth is projected to be relatively high, ranging from 2.0-4.0% for the various branches of industry. For the period 2010-2030 a straightforward projection of 1.5% growth per year is shown for economic activity, whilst transport increases at an average annual rate of 1.0%.

For France the average annual rate of growth of GDP in the period 1980-1990 is projected to be 1.7%. The rate of growth of energy intensive branches of industry in this period is 1.2%, whilst the metal products industry and other industry grow at 1.5%. Growth of transport is similar to West Germany and amounts to about 1.7% per year.

For the period 1990-2000 average annual growth of GDP is projected to be 2.8%. in this period the sector services and government grow at an average annual rate of 3.6%. The projections of the growth rates for the period 2000-2030 are similar to those of West Germany.

For Belgium the projected rate of growth of GDP for the period 1980-1990 is very modest at an average rate of 1.2%. Accordingly the growth rates for transport are lower than in West Germany and France.
In the period 1990-2000 a modest improvement of economic activity is shown, resulting in an average rate of growth of GDP of 2.3% per year. For the period 2000-2030 the rates of growth are assumed to be similar to those of West Germany and France.

For the United Kingdom the average annual rate of growth of GDP in the period 1980-1990 is assumed to be 1.9%. The basic industry and the chemical industry are growing at 1.7% per year, as compared to 2.9% for metal industry and other industry. For the period 1990-1999 these percentages are respectively 1.9% and 1.4%. Private transport grows at an annual average rate of 1.8% as compared to 1.3% for other transport.
For the period 2000-2030 the rates of growth are assumed to be the same as in the other countries of this study.

Table 6.2. Annual rate of growth per activity, realisation 1980-1983 and projections for 1983-2030.

West Germany	80/ 83	83/ 90	80/ 90	90/ 2000	2000/ 2010	2010/ 2020	2020/ 2030
1.basic industry	-1.9	2.2	1.0	1.2	2.0	1.5	1.5
2.chemical ind.	-1.9	2.2	1.0	1.2	3.5	1.5	1.5
3.metal products ind.	-0.7	2.8	1.7	3.2	4.0	1.5	1.5
4.other industry	-0.7	2.8	1.7	3.2	2.2	1.5	1.5
5.construction	-2.9	2.2	0.6	2.5	2.2	1.5	1.5
6.private cars (petrol and lpg)			1.7	1.7	1.6	1.0	1.0
7.other road transport			1.8	1.8	1.8	1.0	1.0
8.railway traffic			2.9	2.9	1.8	1.0	1.0
9.shipping (interior)			1.8	1.8	1.8	1.0	1.0
10.air traffic			2.0	2.0	1.8	1.0	1.0
11.agriculture	4.7	-0.2	1.3	0.0	1.8	1.5	1.5
12.services and gov.	0.9	2.7	2.2	3.0	1.9	1.5	1.5
13.households/dwellings	.002	.002	.002	.002	0.5	0.5	0.5
14.private cars (diesel)			1.7	1.7	1.6	1.0	1.0

France	80/ 83	83/ 90	80/ 90	90/ 2000	2000/ 2010	2010/ 2020	2020/ 2030
1.basic industry	1.1	1.2	1.2	1.6	2.0	1.5	1.5
2.chemical ind.	1.1	1.2	1.2	1.6	3.5	1.5	1.5
3.metal products ind.	0.1	2.0	1.5	2.2	4.0	1.5	1.5
4.other industry	0.1	2.0	1.5	2.2	2.2	1.5	1.5
5.construction	-1.1	0.5	0.0	1.0	2.2	1.5	1.5
6.private cars (petrol and lpg)			1.7	1.7	1.6	1.0	1.0
7.other road transport			1.8	1.8	1.8	1.0	1.0
8.railway traffic			2.9	2.9	1.8	1.0	1.0
9.shipping (interior)			1.8	1.8	1.8	1.0	1.0
10.air traffic			2.0	2.0	1.8	1.0	1.0
11.agriculture	1.6	1.0	1.2	1.0	1.8	1.5	1.5
12.services and gov.	1.3	2.7	2.3	3.6	1.9	1.5	1.5
13.households/dwellings			0.2	0.2	0.5	0.5	0.5
14.private cars (diesel)			1.7	1.7	1.6	1.0	1.0

Table 6.2 (continued) Annual rate of growth per activity, realisation 1980-1983 and projections for 1983-2030.

Belgium	80/83	83/90	80/90	90/2000	2000/2010	2010/2020	2020/2030
1.basic industry	-2.1	0.6	0.0	0.9	2.0	1.5	1.5
2.chemical ind.	-2.1	0.6	0.0	0.9	3.5	1.5	1.5
3.metal products ind.	-0.3	2.3	1.5	2.4	4.0	1.5	1.5
4.other industry	-0.3	2.3	1.5	2.4	2.2	1.5	1.5
5.construction	7.5	0.3	-2.1	2.0	2.2	1.5	1.5
6.private cars (petrol and lpg)			1.7	1.7	1.6	1.0	1.0
7.other road transport			1.2	1.2	1.8	1.0	1.0
8.railway traffic			1.2	1.2	1.8	1.0	1.0
9.shipping (interior)			1.2	1.2	1.8	1.0	1.0
10.air traffic			1.2	1.2	1.8	1.0	1.0
11.agriculture	1.7	-0.7	0.0	0.0	1.8	1.5	1.5
12.services and gov.	1.1	1.7	1.5	2.5	1.9	1.5	1.5
13.households			0.6	0.6	0.5	0.5	0.5
14.private cars (diesel)			1.7	1.7	1.6	1.0	1.0

United Kingdom	80/83	83/90	80/90	90/2000	2000/2010	2010/2020	2020/2030
1.basic industry	0.2	2.3	1.7	1.9	2.0	1.5	1.5
2.chemical ind.	0.2	2.3	1.7	1.9	3.5	1.5	1.5
3.metal products ind.	0.6	3.9	2.9	1.4	4.0	1.5	1.5
4.other industry	0.6	3.9	2.9	1.4	2.2	1.5	1.5
5.construction	-1.6	2.5	1.3	3.0	2.2	1.5	1.5
6.private cars (petrol and lpg)			1.8	1.8	1.6	1.0	1.0
7.other road transport			1.3	1.3	1.8	1.0	1.0
8.railway traffic			1.3	1.3	1.8	1.0	1.0
9.shipping (interior)			1.3	1.3	1.8	1.0	1.0
10.air traffic			1.3	1.3	1.8	1.0	1.0
11.agriculture	2.3	3.0	2.8	0.0	1.8	1.5	1.5
12.services and gov.	2.0	1.5	1.6	3.0	1.9	1.5	1.5
13.households			0.2	0.2	0.5	0.5	0.5
14.private cars (diesel)			1.8	1.8	1.6	1.0	1.0

Fuel mix

For all activities the fuel mix for 1980 has been established on the basis of published energy statistics (IEA/OECD,1982). For the reference year 1990 the fuel mix is calculated on the basis of the projections in the study Energy 2000 (Guilmot et al, 1985). As the level of aggregation of the EMAC-model is lower than the aggregation level of Energy 2000, some additional assumptions had to be made on the fuel mix per activity.
For each country the fuel mix for non-energy activities is shown in the Tables B.1-B.4 in Appendix B of this report. For the non-energy sectors the fuel mix is assumed to be constant for the years after 1990, with the exception of Belgium. For Belgium some further penetration of electricity consumption is specified for the year 2000 (see appendix B). The fuel mix for the sectors electricity generation and refineries are taken from the study Energy 2000 for the period 1980-2000. They are shown for 1980, 1990 and 2000 in the tables B.5-B.8 of appendix B. After the year 2000 they are assumed to be constant.

Energy efficiency improvement.

In general, energy efficiency improvement, i.e. the reduction of energy consumption per unit of product, is the result of technical progress and the induced efficiency improvement due to increasing real energy prices. The energy efficiency indices in this study are 1.00 in the year 1980 and will be lower in the reference years 1990, 2000, 2010, 2020 and 2030. The energy efficiency indices are for the years 1990 and 2000 based on the study Energy 2000. As before, some additional assumptions had to be made because of a lower level of aggregation of the EMAC-model. The relevant assumptions for energy efficiency improvement of fossil fuel are shown in Table 6.3.
For the period 2000-2010 efficiency improvement develops according to the projections of the Central Planning Bureau for the Netherlands (CPB, 1986). For the period 2010-2030 an average annual rate of efficiency improvement of 0.5% is assumed for all non-energy activities. Energy efficiency improvement of electricity consumption is assumed to be the same in all countries and is shown in table 6.4. The average annual rate of change in the projections for the period 2000-2030 is about 0.5% per year for all activities, with the exception of households where some further penetration of electricity consumption results in an increase of electricity consumption per dwelling.

Table 6.3. Energy efficiency indices for fossil fuel consumption 1990-2030 (1980=1.00).

West Germany	1990	2000	%	2010	%	2020	%	2030
1.basic ind.	.83	.69	.3	.67	.5	.63	.5	.60
2.chemical ind.	.83	.69	.5	.66	.5	.63	.5	.60
3.metal prod. ind.	.83	.69	.6	.65	.5	.62	.5	.59
4.other ind.	.83	.69	.9	.63	.5	.60	.5	.57
5.construction	1.0	.95	.4	.91	.5	.87	.5	.83
6.private cars (petrol and lpg)	.9	.8	.5	.76	.5	.72	.5	.68
7.other road traffic	.9	.8	.5	.76	.5	.72	.5	.68
8.railway	.9	.8	.5	.76	.5	.72	.5	.68
9.shipping (interior)	.9	.8	.5	.76	.5	.72	.5	.68
10.air	.9	.8	.5	.76	.5	.72	.5	.68
11.agriculture	.83	.69	.5	.66	.5	.63	.5	.60
12.services/governm.	.9	.8	.7	.75	.5	.71	.5	.68
13.households	.9	.8	.4	.77	.5	.73	.5	.69
14.private cars (diesel)	.9	.8	.5	.76	.5	.72	.5	.68

France	1990	2000	%	2010	%	2020	%	2030
1.basic ind.	.77	.65	.3	.63	.5	.60	.5	.57
2.chemical ind.	.77	.65	.5	.62	.5	.59	.5	.56
3.metal prod. ind.	.77	.65	.6	.61	.5	.58	.5	.55
4.other ind .	.77	.65	.9	.59	.5	.56	.5	.53
5.construction	1.0	.95	.4	.91	.5	.87	.5	.82
6.private cars (petrol and lpg)	.9	.8	.5	.76	.5	.72	.5	.69
7.other road traffic	.9	.8	.5	.76	.5	.72	.5	.69
8.railway	.9	.8	.5	.76	.5	.72	.5	.69
9.shipping (interior)	.9	.8	.5	.76	.5	.72	.5	.69
10.air	.9	.8	.5	.76	.5	.72	.5	.69
11.agriculture	.83	.69	.5	.66	.5	.63	.5	.60
12.services/governm.	.9	.8	.7	.75	.5	.71	.5	.68
13.households	.88	.68	.4	.65	.5	.62	.5	.59
14.private cars (diesel)	.9	.8	.5	.76	.5	.72	.5	.69

Table 6.3 (continued): Energy efficiency indices for fossil fuel consumption 1990-2030 (1980=1.00).

Belgium	1990	2000	%	2010	%	2020	%	2030
1.basic ind.	.8	.66	.3	.64	.5	.61	.5	.58
2.chemical ind.	.8	.66	.5	.63	.5	.60	.5	.57
3.metal prod. ind.	.8	.66	.6	.62	.5	.59	.5	.56
4.other ind.	.8	.66	.9	.60	.5	.57	.5	.54
5.construction	1.0	.95	.4	.91	.5	.87	.5	.82
6.private cars (petrol and lpg)	.9	.8	.5	.76	.5	.72	.5	.69
7.other road traffic	.9	.8	.5	.76	.5	.72	.5	.69
8.railway	.9	.8	.5	.76	.5	.72	.5	.69
9.shipping (interior)	.9	.8	.5	.76	.5	.72	.5	.69
10.air	.9	.8	.5	.76	.5	.72	.5	.69
11.agriculture	.83	.69	.5	.66	.5	.62	.5	.60
12.services/governm.	.9	.8	.7	.75	.5	.71	.5	.68
13.households	.9	.8	.4	.77	.5	.73	.5	.70
14.private cars (diesel)	.9	.8	.5	.76	.5	.72	.5	.69

United Kingdom	1990	2000	%	2010	%	2020	%	2030
1.basic ind.	.81	.76	.3	.74	.5	.70	.5	.67
2.chemical ind.	.81	.76	.5	.72	.5	.68	.5	.65
3.metal prod. ind.	.81	.76	.6	.71	.5	.68	.5	.64
4.other ind.	.81	.76	.9	.69	.5	.66	.5	.62
5.construction	1.0	.95	.4	.90	.5	.86	.5	.81
6.private cars (petrol and lpg)	.89	.8	.5	.76	.5	.72	.5	.69
7.other road traffic	.9	.8	.5	.76	.5	.72	.5	.69
8.railway	.9	.8	.5	.76	.5	.72	.5	.69
9.shipping (interior)	.9	.8	.5	.76	.5	.72	.5	.69
10.air	.9	.8	.5	.76	.5	.72	.5	.69
11.agriculture	.83	.69	.5	.66	.5	.63	.5	.60
12.services/governm.	.9	.8	.7	.75	.5	.71	.5	.68
13.households	.88	.71	.4	.68	.5	.65	.5	.61
14.private cars (diesel)	.85	.8	.5	.76	.5	.72	.5	.69

Table 6.4. Energy efficiency indices for electricity consumption 1990 -2030 (1980=1.00): West Germany, France, Belgium and the United Kingdom.

	1990	%	2000	%	2010	%	2000	%	2030
1.basic ind.	.95	.5	.90	.5	.86	.5	.82	.5	.78
2.chemical ind.	.95	.5	.90	.5	.86	.5	.82	.5	.78
3.metal prod. ind.	.95	.5	.90	.5	.86	.5	.82	.5	.78
4.other ind.	.95	.5	.90	.5	.86	.5	.82	.5	.78
5.construction	1.0	.5	.95	.5	.90	.5	.86	.5	.82
6.private cars (petrol and lpg)	-		-		-		-		-
7.other road traffic	-		-		-		-		-
8.railway	.95	.5	.90	.5	.90	.5	.86	.5	.82
9.shipping (interior)	-		-		-		-		-
10.air	-		-		-		-		-
11.agriculture	.95	.5	.90	.5	.86	.5	.82	.5	.78
12.services/governm.	.95	.3	.92	.5	.88	.5	.84	.5	.80
13.households	.95	.0	.95	-.6	1.01	0	1.01	0	1.01
14.private cars (diesel)	-		-		-		-		-

Emission factors

The calculation of the emissions of SO_2 and NO_x is based on energy consumption per fuel type per activity and the emission factors for SO_2 and NO_x. The emission factors reflect the emission of pollutants per unit of energy consumed, before abatement.
As far as SO_2 emission factors are concerned, at first an emission factor was defined, assuming a 1% sulphur content of the fuels used. Next the sulphur content of the fuels was defined and finally the emission of SO_2 was calculated, taking into account the standard 1% emission factor and the sulphur content of the fuels.
Since all abatement measures are reflected in the abatement indices (Tables B.5 - B.8, Annex B), the emission factors remain constant all over the period 1980-2030. The emissions factors and the sulphur content of fuels, as they have been used in the EMAC-model are shown in the Tables B.1 - B.4.

About the values of the emission factors the following is to be noticed. Until now, no consistent data base is available for the year 1980, that contains data for energy consumption per fuel type per activity and the relevant emission factors for SO_2 and NO_x per country. Several emission inventories exist such as EMEP (1987), OECD (1987), IIASA (1987), ECE(1987) and PHOXA

(1987). The inventories differ considerably and most of them only show the annual emissions of SO_2 and NO_x for a small number of highly aggregated activities, such as total industry, total transport and non-industrial combustion. The PHOXA emission inventory is more detailed but differs considerably from the ECE-data. Also for the other inventories the reported emission levels for 1980 differ considerably from each other. The emission factors, that are used in this study, have been taken from various sources such as PHOXA (1987) and TNO (1988).

In order to arrive at a set of emission levels for SO_2 and NO_x that are compatible with the ECE figures for 1980 the sulphur percentages and the emission factors for NO_x have been adjusted . The resulting emission factors and sulphur percentages are shown in the Tables B.1 - B.4. Because of the absence of a consistent data base the emission factors and sulphur percentages may differ considerably from emission factors reported in other studies.

Abatement policy

In the EMAC-model abatement policy is reflected in abatement indices, that are specified per activity per fuel type for all of reference years. The indices are 1.00 in the base year 1980 and become smaller when abatement measures are enforced. For example an abatement index of 0.80 reflects an abatement policy that results in a 20 % reduction of emissions per unit of energy consumed. The reduction of the emissions in the case of SO_2 may, for example, be the result of a reduction of the sulphur content of fuels or the application of flue gas desulphurisation or other emission reducing measures. Also a combination of these measures may lead to the final emission reduction per unit of energy consumed. In the case of NO_x emissions the abatement policy reflects for example the application of low NO_x burners or catalytic reduction.

It should be emphasised that uncertainty exists about the most up to date abatement plans in the countries in question, particularly as far as detailed policy plans per activity are concerned. In general, governments have specified overall emission reduction targets, without specifying in detail how these targets are to be achieved. The assumed abatement indices should be considered - until more detailed plans are available - as rather rough indicators of how the emission reductions could be reached.

The abatement indices that are used to calculate the results that are presented in paragraph 6.2.5, are shown in the Tables B.5. - B.8. The abatement indices that are shown in this study for the year 2000 have been adjusted to arrive at the projected emission levels for the year 2000, as presented in ECE (1987). The abatement indices show how much abatement should take place per activity in order to arrive at the projected emission levels. Obviously, as the abatement policy is still subject to political decision making, the final degree of pollution abatement for different activities may differ considerably. It could well be decided to reduce emissions more intensively for a specific activity. Therefore, the abatement indices, presented in this study, should be considered as a consistent example of possible abatement measures that are required to reach the emission targets of ECE (1987).

6.2.4. Emission due to processes.

For the process emissions the following emissions levels are projected. The levels for 1980 and 1990 are taken from ECE (1987). For the years 2000-2030 it was assumed that the increase in process emissions due to economic grow is offset by increased pollution abatement. Therefore the process emissions remain at the same level in the period 2000-2030. The projected levels of process emissions of SO_2 and NO_x are shown in Table 6.5.

Table 6.5. Projected levels of process emissions of SO_2 and NO_x, 1980-2030.

SO_2	1980	1990	2000	2010	2020	2030
West Germany	110	110	110	110	110	110
France	383	227	200	200	200	200
Belgium	80	65	55	55	55	55
United Kingdom	0	0	0	0	0	0
NO_x						
West Germany	20	20	20	20	20	20
France	43	52	30	30	30	30
Belgium	20	20	20	20	20	20
United Kingdom	100	100	100	100	100	100

6.2.5. Results

Total emissions per country

In this paragraph the results of the model calculations are presented for the base year 1980 and for the reference years 1990, 2000, 2010, 2020 and 2030. It should be stressed that the results are conditional projections: they only hold if the set of assumptions mentioned above is correct. The results are summarised in Table 6.6 and in the Figures 6.3 and 6.4

Emissions per region per country.

The emissions of SO_2 and NO_x per aggregated region for the EMAC-countries are shown in the tables 6.7 and 6.8. The tables show that the regional distribution of emissions in the EMAC projections is rather stable. Some relatively minor changes in the regional distribution take place due to a different regional impact of abatement measures and the regional distribution of power plants. For example, if a region has a large share in power production by coal and oil, the impact of flue gas desulphurisation in this region will be large and the relative share in sulphur emissions will decline.

Emissions per EMAC-country per activity

The contribution of each activity to the national totals of emissions of SO_2 and NO_x for all reference years is shown in the Tables B.9 - B.12 (Annex B).

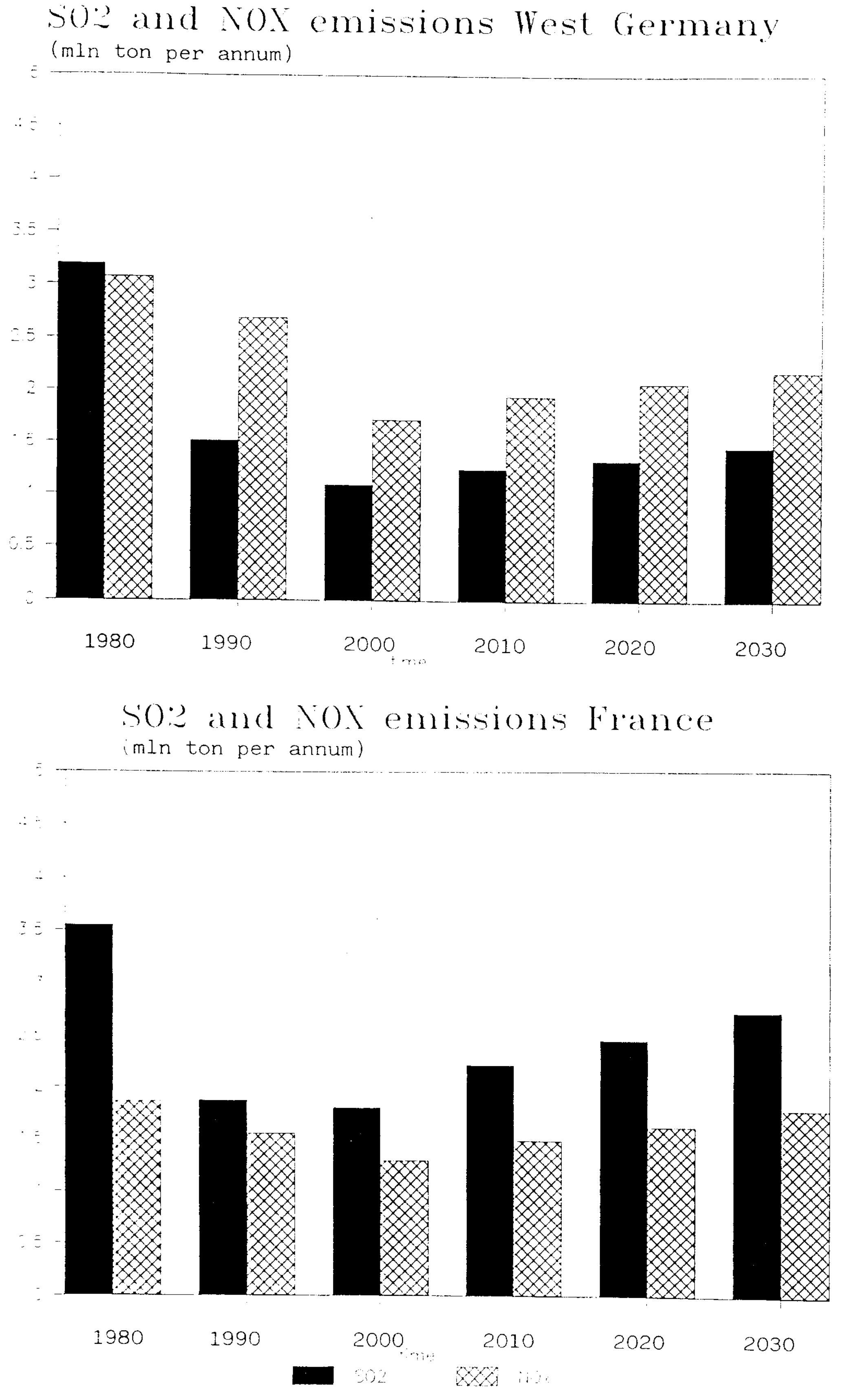
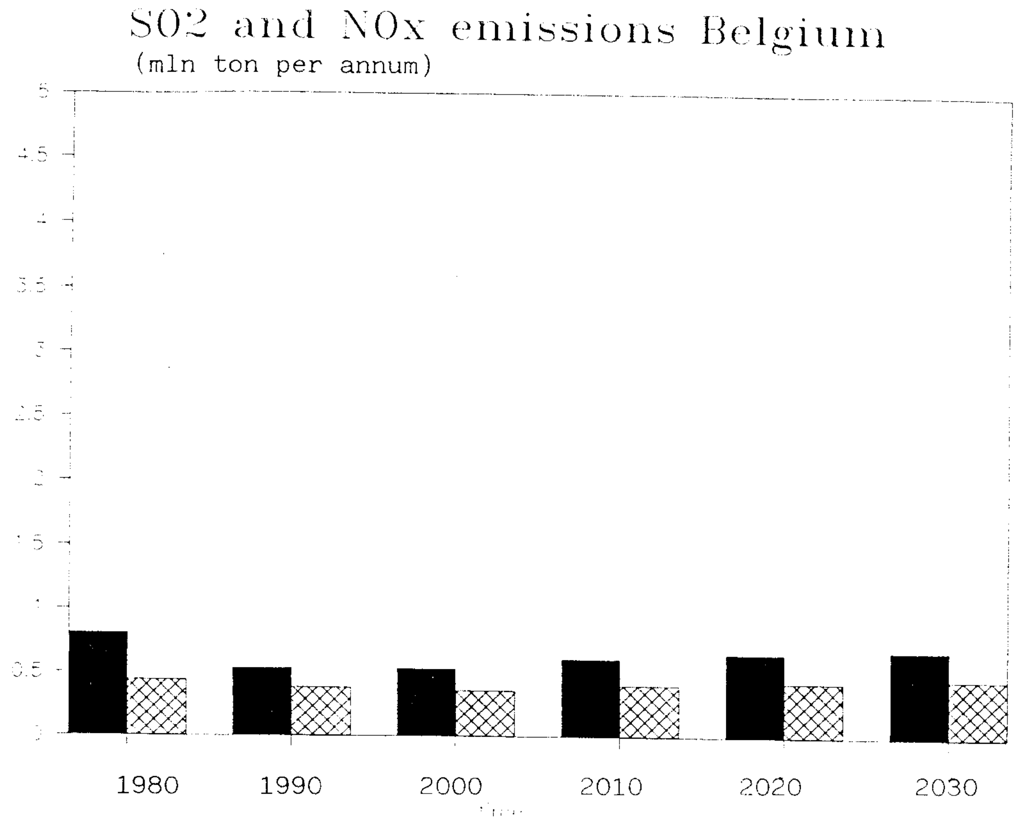


Figure 6.3. Emission levels for SO_2 and NO_x in the EMAC countries.



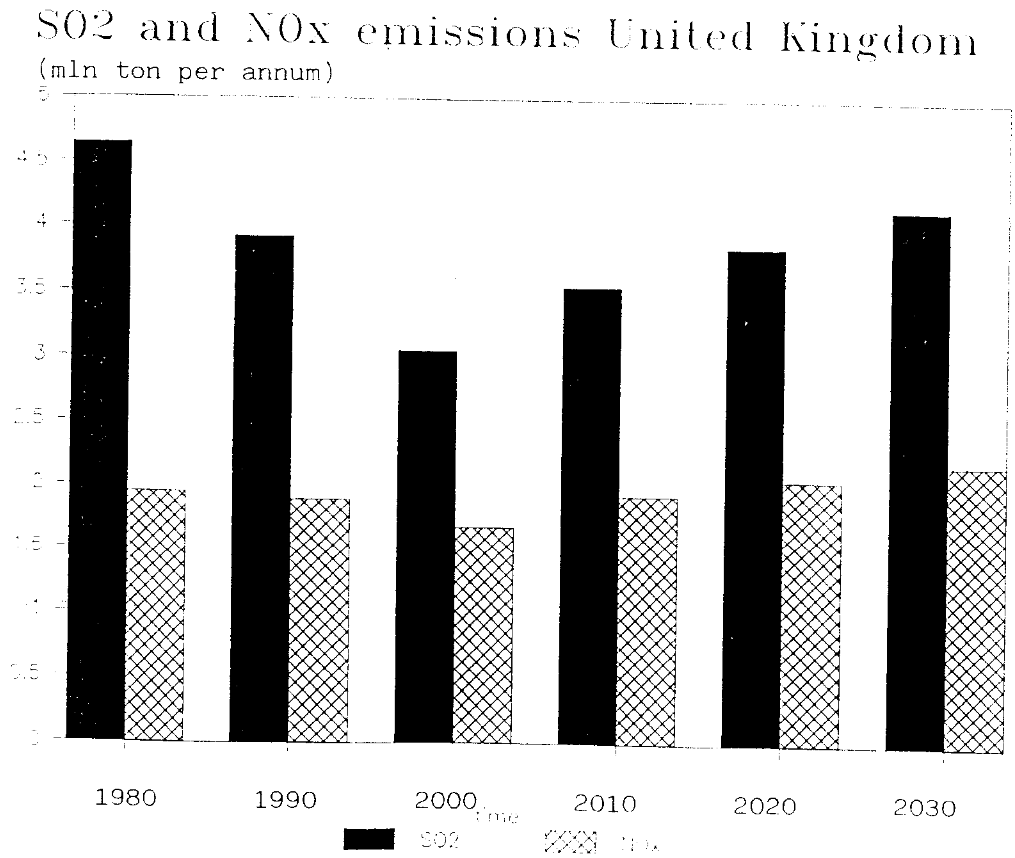


Figure 6.4. Emission levels of SO_2 and NO_x in the EMAC countries.

Table 6.6. SO_2 and NO_x emissions in the EMAC-countries in the period 1980 - 2030 (kiloton).

SO_2	1980	1990	2000	2010	2020	2030
W.Germany						
combustion emissions	3084	1407	981	1136	1225	1351
process emissions	110	110	110	110	110	110
total	**3194**	**1517**	**1091**	**1246**	**1335**	**1461**
index	1.00	.47	.34	.39	.42	.46
France						
combustion emissions	3165	1650	1610	2023	2265	2521
process emissions	383	227	200	200	200	200
total	**3548**	**1877**	**1810**	**2223**	**2465**	**2721**
index	1.00	.53	.51	.63	.69	.77
Belgium						
combustion emissions	726	467	479	557	599	627
process emissions	80	65	55	55	55	55
total	**806**	**532**	**534**	**612**	**654**	**682**
index	1.00	.66	.66	.76	.81	.85
United Kingdom						
combustion emissions	4641	3910	3054	3545	3847	4149
process emissions	0	0	0	0	0	0
total	**4641**	**3910**	**3054**	**3545**	**3847**	**4149**
index	1.00	.84	.66	.76	.83	.89

NO_x	1980	1990	2000	2010	2020	2030
W.Germany						
combustion emissions	3051	2668	1711	1935	2052	2159
process emissions	20	20	20	20	20	20
total	**3071**	**2688**	**1731**	**1955**	**2072**	**2179**
index	1.00	.88	.56	.63	.67	.71
France						
combustion emissions	1822	1503	1259	1461	1602	1758
process emissions	43	52	30	30	30	30
total	**1865**	**1555**	**1289**	**1491**	**1632**	**1788**
index	1.00	.83	.69	.80	.88	.96
Belgium						
combustion emissions	420	366	340	387	410	439
process emissions	20	20	20	20	20	20
total	**440**	**386**	**360**	**407**	**430**	**459**
index	1.00	.88	.82	.92	.98	1.04
United Kingdom						
combustion emissions	1847	1790	1575	1820	1955	2095
process emissions	100	100	100	100	100	100
total	**1947**	**1890**	**1675**	**1920**	**2055**	**2195**
index	1.00	.97	.86	.99	1.06	1.13

Table 6.7. SO_2 emissions per country, per aggregated region (kiloton) and regional shares for 1980, 2000 and 2030.

	1980	share	1990	2000	share	2010	2020	2030	share
W. Germany									
total	3084	1.0	1407	981	1.0	1136	1225	1351	1.0
north	663	.22	336	238	.24	276	298	330	.25
mid	1668	.54	656	442	.45	513	533	611	.45
south	753	.24	414	300	.31	346	378	410	.30
France									
total	3165	1.0	1650	1610	1.0	2023	2265	2521	1.0
north	2129	.67	968	945	.59	1181	1393	1573	.62
south	1036	.33	682	665	.41	842	872	948	.38
Belgium									
total	726	1.0	467	479	1.0	557	599	628	1.0
west	202	.28	126	140	.29	163	169	185	.30
north east	285	.39	184	182	.38	204	227	234	.37
south	238	.33	155	156	.33	189	203	208	.33
United Kingdom									
total	4641	1.0	3910	3054	1.0	3545	3847	4149	1.0
north	728	.16	596	429	.14	496	538	579	.14
mid	2189	.47	1900	1587	.52	1845	2004	2164	.52
south	1724	.37	1413	1038	.34	1204	1304	1405	.34

Table 6.8. NO_x emissions per country, per aggregated region (kiloton) and regional shares for 1980, 2000 and 2030.

	1980	share	1990	2000	share	2010	2020	2030	share
W. Germany									
total	3051	1.0	2668	1711	1.0	1935	2052	2159	1.0
north	632	.21	598	381	.22	432	459	484	.22
mid	1551	.51	1279	787	.46	891	944	994	.46
south	867	.28	791	542	.32	612	648	680	.32
France									
total	1822	1.0	1503	1259	1.0	1461	1602	1758	1.0
north	1053	.58	810	687	.55	782	913	1020	.58
south	769	.42	692	571	.45	679	689	738	.42
Belgium									
total	420	1.0	366	340	1.0	387	410	439	1.0
west	106	.25	95	92	.27	105	110	119	.27
north east	188	.45	159	144	.42	162	172	183	.42
south	125	.30	110	103	.36	119	126	136	.32
Britain									
total	1847	1.0	1790	1575	1.0	1820	1955	2095	1.0
north	267	.15	258	214	.14	248	266	285	.14
mid	797	.43	792	742	.47	861	927	995	.47
south	782	.42	739	617	.39	711	706	814	.39

6.3. Emission of SO_2 and NO_x in the other countries.

In Table 6.9 and Table 6.10 the emission scenarios are shown for the DAS-regions 32 and 33. The data for the year 2000 are derived from national statements on the expected emission of SO_2 and NO_x by the end of the century. The emission data for the period 2000 - 2030 have been calculated assuming, that the relative change in the emission will be similar to the change in the EMAC-countries (cf. 6.2.).

Table 6.9. Emission of SO_2 (kiloton) in the period 1980 - 2030 in the DAS-regions 32 and 33.

COUNTRY	1980	1985	2000	2030
Czechoslovakia	3100	3150	2140	2970
German Democr. Rep.	4000	4000	2800	3890
Hungary	1633	1420	1140	1580
Poland	4100	4300	4900	6810
REGION 32	12833	12870	10980	15250
Austria	354	170	110	150
Denmark	438	326	230	320
Finland	584	370	270	370
Italy	3800	2250	2600	3610
Norway	141	100	85	120
Portugal	266	300	300	420
Spain	3250	3250	3050	4240
Sweden	483	272	160	220
Switzerland	126	95	60	80
USSR	12800	11100	8900	12360
REGION 33	22242	18233	15765	21900

Table 6.10. Emission of NO_x (kiloton) in the period 1980 - 2030 in the DAS-regions 32 and 33.

COUNTRY	1980	1985	2000	2030
Czechoslovakia	1204	1100	950	1240
German Democr. Rep.	300	300	300	390
Hungary	400	300	300	390
Poland	840	840	840	1100
REGION 32	2744	2540	2390	3130
Austria	216	216	150	200
Denmark	251	238	325	430
Finland	280	248	305	400
Italy	1480	1750	1500	1970
Norway	215	215	215	280
Portugal	166	192	190	250
Spain	800	951	950	1240
Sweden	328	305	240	310
Switzerland	196	214	150	200
USSR	2790	2930	2930	3840
REGION 33	6722	7259	6955	9110

6.4. Emission of ammonia.

Up till now hardly any policy statements have been formulated on abatement of the emission of NH_3. Therefore it is not possible to present emission data for the period 1980 - 2030 , which are based on such statements. For the time being the emission in this period is assumed to remain constant. However, since NH_3-emissions abroad do not contribute much to the deposition of acid in the Netherlands, changes in these data will not influence the results of the DAS-model to a large extent.

6.5. Emission of VOC.

Only few countries have collected data on the present amount of VOC emitted, and even less countries have made projections of the extent of emission in the future. In Table 6.11 the data which have been collected at present are shown (OECD, 1988). Some information on future emissions has been reported by ECE, most figures in Table 6.19 for emission in the future however are only "guestimates".

Table 6.11. Scenarios for anthropogenic VOC-emissions in the regions 21 - 33 (kiloton).

COUNTRY	EMISSION 1980	1985	2000	2030
Belgium	313	310	290	290
France	1972	2150	1500	1500
Luxembourg	11	10	10	10
German Fed. Rep.	2471	1800	1200	1200
Ireland	77	80	75	70
United Kingdom	1675	1990	1950	1950
German Democratic Rep.	580	550	400	400
Czechoslovakia	370	350	250	250
Hungary	350	330	250	250
Poland	940	900	650	650
TOTAL REGION 32	2240	2130	1550	1550
Austria	251	250	200	200
Denmark	173	170	140	140
Finland	161	160	110	110
Italy	1566	1600	1300	1300
Norway	139	160	110	110
Portugal	159	160	150	150
Spain	791	790	750	750
Sweden	423	400	290	290
Switzerland	310	320	270	270
USSR	4480	4260	3100	3100
TOTAL REGION 33	8450	8270	6420	6420

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ANNEX A

Table A.1. Antropogenic SO_2-emission in the Netherlands in 1980 (kiloton).

	Combustion solid	oil	gas	sum	Proces	Total
STATIONARY SOURCES						
Agriculture		4.7	0.1	4.8		4.8
Oil/gas exploration			0.4	0.4		0.4
Coke production			0.8	0.8		0.8
Refineries	4.5	91.9	6.0	102.3	19	121.3
Food industry		7.6		7.7		7.7
Textile industry		0.8		0.8		0.8
Paper industry		0.7		0.8		0.8
Chemical industry	1.8	12.2	6.3	20.3	32.3	52.6
Building materials ind.	0.9	3.7	0.0	4.6		4.6
Primary metal industry	1.7	1.5	1.6	4.8	8.9	13.8
Other metal industry		2.0		2.0		2.0
Other industry				0.1	3.4	3.5
Power plants	41.4	153.4	0.4	195.3		195.3
Construction		1.2		1.2		1.2
Domestic	0.8	5.2	0.3	6.2		6.2
Services	0.8	6.4	0.1	7.3		7.3
Incineration of waste					2.9	2.9
Subtotal	52	291	16	359	66	425
MOBILE SOURCES						
Passenger cars						3.4
Duty trucks						12
Ships						19
Off-highway						3
Other						0.4
Subtotal						38
TOTAL						463

Table A.2. Antropogenic NO_x-emission in the Netherlands in 1980 (kiloton).

	Combustion: solid	oil	gas	sum	Proces	Total
STATIONARY SOURCES						
Agriculture		1.0	7.3	8.3		8.3
Oil/gas exploration			0.7	0.7		0.7
Coke production			0.4	0.4		0.4
Refineries	1.5	12.8	5.0	19.3		19.3
Food industry		1.2	3.5	4.7		4.7
Textile industry		0.1	0.3	0.5		0.5
Paper industry		0.1	0.9	1.0		1.0
Chemical industry	0.6	2.9	16.3	19.8	22	41.8
Building materials ind.	1.3	1.4	4.2	6.9		6.9
Primary metal industry	2.0	0.4	6.1	8.5		8.5
Other metal industry		0.4	1.3	1.7		1.7
Other industry			0.5	0.5		0.5
Power plants	18.3	33.8	28.1	80.3		80.3
Construction		0.4	0.3	0.7		0.7
Domestic	0.1	2.1	23.2	25.4		25.4
Services	0.3	1.8	6.5	8.6		8.6
Incineration of waste					4.1	4.1
Subtotal	24	58	105	187	26	213
MOBILE SOURCES						
Passenger cars						162
Duty trucks						115
Ships						33
Off-highway						23
Other						3
Subtotal						336
TOTAL						549

Table A.3. Percentual distribution of SO_2 combustion emissions over the 20 Dutch areas (1980).

SOURCE \ REGION	1	2	3	4	5	6	7	8	9	10
agriculture	0.8	0.1	0.8	0.0	0.0	0.0	0.0	2.2	4.3	2.7
refineries	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
fertilizer ind.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
chemical ind.	9.6	0.0	1.0	0.0	9.1	0.0	0.0	0.0	0.0	0.0
prim. metal ind.	8.8	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0
other high sources	7.9	0.2	7.1	0.0	0.1	1.4	1.6	2.7	0.0	0.3
other low sources	4.1	4.2	3.0	2.5	5.1	3.9	2.5	5.6	6.8	3.3
power plants	2.7	0.0	0.0	7.9	0.1	13.2	0.0	4.6	8.3	0.2
private cars	2.5	3.7	2.5	2.5	4.9	4.9	1.2	6.2	8.6	2.5
trucks	3.1	3.8	2.9	2.8	4.4	2.2	2.1	6.9	9.1	2.8
other traffic	1.7	2.0	1.4	1.4	2.6	2.9	1.1	3.4	4.3	1.7
ships	0.2	0.5	0.0	0.3	0.2	0.6	0.3	9.1	1.2	0.1
domestic	3.9	4.0	2.9	2.4	4.9	3.7	2.5	5.4	6.6	3.2

SOURCE \ REGION	11	12	13	14	15	16	17	18	19	20
agriculture	23.7	30.2	14.8	0.3	2.9	6.6	1.4	0.3	8.8	0.0
refineries	2.3	0.0	94.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0
fertilizer ind.	0.0	0.0	56.6	43.6	0.0	0.0	0.0	0.0	0.0	0.0
chemical ind.	3.3	0.1	56.0	1.5	1.9	0.0	0.0	0.0	0.0	17.6
prim. metal ind.	60.5	0.0	0.0	23.2	0.0	0.0	0.0	5.5	0.0	0.0
other high sources	2.0	2.5	32.2	13.9	16.9	0.5	0.4	0.0	0.0	10.3
other low sources	14.5	11.1	12.2	2.5	0.4	2.6	3.5	4.4	3.2	4.8
power plants	9.8	0.3	9.4	2.8	25.5	0.0	0.0	0.0	15.3	0.0
private cars	14.8	9.9	13.6	1.2	4.9	1.2	2.5	3.7	3.7	4.9
trucks	12.2	9.5	13.7	2.1	5.2	2.5	2.9	4.3	3.7	3.7
other traffic	51.3	5.4	6.9	1.1	2.6	1.4	1.7	2.6	1.7	2.6
ships	5.4	0.1	63.4	15.8	1.0	0.2	0.3	0.1	0.9	0.4
domestic	14.1	10.8	11.8	2.4	3.7	2.5	3.4	4.3	3.1	4.6

Table A.4. Percentual distribution of NO_x combustion emissions over the 20 Dutch areas (1980)

SOURCE / REGION	1	2	3	4	5	6	7	8	9	10
agriculture	0.5	0.2	1.2	0.2	0.2	0.0	0.0	2.4	2.4	1.0
refineries	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
fertilizer ind.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
chemical ind.	9.7	0.0	0.7	0.0	1.9	0.0	0.0	0.0	0.0	0.0
prim. metal ind.	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
other high sources	14.6	0.6	3.0	0.8	0.5	2.2	1.6	3.2	0.0	0.6
other low sources	3.9	4.0	2.9	2.3	4.9	3.7	2.5	5.4	6.5	3.2
power plants	7.8	8.8	0.0	6.3	0.1	6.1	0.0	5.3	4.1	0.1
private cars	3.1	3.7	2.8	2.7	4.2	6.0	2.1	6.6	8.5	2.8
trucks	2.9	3.7	2.8	2.7	4.2	6.3	2.1	6.7	8.7	2.7
other traffic	2.9	3.4	2.6	2.4	4.0	5.3	2.0	5.9	7.7	2.6
ships	0.6	1.2	0.0	0.9	0.5	1.6	0.9	24.8	3.3	0.2
domestic	3.9	4.0	2.9	2.4	4.9	3.7	2.5	5.4	6.6	3.2

SOURCE / REGION	11	12	13	14	15	16	17	18	19	20
agriculture	11.6	54.3	14.5	0.2	2.4	1.7	1.0	0.7	5.6	0.0
refineries	2.2	0.0	93.8	3.9	0.0	0.0	0.0	0.0	0.0	0.0
fertilizer ind.	35.1	0.0	13.2	15.2	0.0	0.0	0.0	0.0	0.0	36.5
chemical ind.	0.7	1.1	15.2	14.8	4.4	0.0	0.0	0.0	0.2	51.4
prim. metal ind.	98.8	0.0	0.0	0.8	0.0	0.0	0.0	0.1	0.0	0.0
other high sources	4.2	2.8	17.2	1.7	3.9	3.2	14.0	0.8	0.2	25.1
other low sources	14.0	10.7	11.8	2.3	3.7	2.5	3.4	4.3	3.1	4.6
power plants	13.5	0.3	12.9	1.9	25.4	0.0	0.0	0.0	7.3	0.0
private cars	12.5	9.3	13.1	2.1	4.9	2.4	2.9	4.2	3.5	3.7
trucks	11.8	9.1	13.2	2.0	4.9	2.4	2.8	4.1	3.6	3.5
other traffic	18.8	8.7	12.0	1.9	4.4	2.2	2.7	3.8	3.2	3.5
ships	6.3	0.2	40.0	11.5	2.8	0.5	0.9	0.2	2.4	1.2
domestic	14.1	10.8	11.8	2.4	3.7	2.5	3.4	4.3	3.1	4.6

Table A.5 SO_2 emission in the 20 Dutch areas (1980) (kiloton, combustion only).

SOURCE	REGION 1	2	3	4	5	6	7	8	9	10	11
agriculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	1.1
refineries	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4
fertil.ind.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
chem. ind.	1.8	0.0	0.2	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.6
pr. met.ind.	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	2.9
other high	0.7	0.0	0.6	0.0	0.0	0.1	0.1	0.2	0.0	0.0	0.2
other low	0.4	0.4	0.3	0.2	0.5	0.4	0.2	0.6	0.7	0.3	1.4
power plants	5.3	0.0	0.0	15.4	0.2	25.8	0.0	9.0	16.2	0.4	19.1
private cars	0.1	0.2	0.1	0.1	0.2	0.2	0.1	0.3	0.4	0.1	0.7
trucks	0.4	0.5	0.4	0.3	0.5	0.2	0.2	0.8	1.1	0.3	1.4
other traff.	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	1.7
ships	0.0	0.1	0.0	0.1	0.0	0.1	0.1	1.7	0.2	0.0	1.0
domestic	0.5	0.5	0.4	0.3	0.7	0.5	0.3	0.7	0.9	0.4	1.9
Total	9.7	1.8	2.0	16.5	3.9	27.5	1.1	13.6	19.8	1.8	34.4

SOURCE	REGION 12	13	14	15	16	17	18	19	20	SUM
agriculture	1.4	0.7	0.0	0.1	0.3	0.1	0.0	0.4	0.0	4.8
refineries	0.0	96.2	3.9	0.0	0.0	0.0	0.0	0.0	0.0	102
fertil.ind.	0.0	1.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	1.7
chem. ind.	0.0	10.4	0.3	0.4	0.0	0.0	0.0	0.0	3.3	18.6
pr. met.ind.	0.0	0.0	1.1	0.0	0.0	0.0	0.3	0.0	0.0	4.8
other high	0.2	2.7	1.2	1.4	0.0	0.0	0.0	0.0	0.9	8.4
other low	1.1	1.2	0.2	0.0	0.2	0.3	0.4	0.3	0.5	8.7
power plants	0.6	18.4	5.5	49.8	0.0	0.0	0.0	29.9	0.0	195
private cars	0.4	0.6	0.1	0.2	0.1	0.1	0.2	0.2	0.2	4.5
trucks	0.5	1.6	0.2	0.6	0.3	0.4	0.5	0.4	0.4	11
other traff.	0.2	0.2	0.0	0.1	0.0	0.1	0.1	0.1	0.1	3.3
ships	0.0	12.0	3.0	0.2	0.0	0.1	0.0	0.2	0.1	19
domestic	1.5	1.6	0.3	0.5	0.3	0.5	0.6	0.4	0.6	14
Total	5.9	146.6	16.6	53.4	1.4	1.5	2.1	31.9	6.0	397

Table A.6 NO_x emission in the 20 Dutch areas (1980) (kiloton, combustion only).

SOURCE	REGION 1	2	3	4	5	6	7	8	9	10	11
ariculture	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.2	0.1	1.0
refineries	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
fertil.ind.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2
chem. ind.	1.6	0.0	0.1	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.1
pr. met.ind.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4
other high	0.8	0.0	0.2	0.0	0.0	0.1	0.1	0.2	0.0	0.0	0.2
other low	0.4	0.5	0.3	0.3	0.6	0.4	0.3	0.6	0.7	0.4	1.6
power pl.	6.3	7.1	0.0	5.1	0.1	4.9	0.0	4.3	3.3	0.1	10.8
priv. cars	5.0	6.0	4.5	4.4	6.8	9.7	3.4	10.7	13.8	4.5	20.3
trucks	3.3	4.3	3.2	3.1	4.8	7.2	2.4	7.7	10.0	3.1	13.6
oth. traffic	0.8	0.9	0.7	0.6	1.0	1.4	0.5	1.5	2.0	0.7	4.9
ships	0.2	0.4	0.0	0.3	0.2	0.5	0.3	8.2	1.1	0.1	2.1
domestic	1.3	1.4	1.0	0.8	1.7	1.3	0.9	1.9	2.3	1.1	4.8
Total	19.8	20.5	10.1	14.6	15.5	25.6	7.9	35.2	33.3	10.0	69.5

SOURCE	REGION 12	13	14	15	16	17	18	19	20	SUM
ariculture	4.5	1.2	0.0	0.2	0.1	0.1	0.1	0.5	0.0	8.3
refineries	0.0	18.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	19.3
fertil.ind.	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	1.3	3.5
chem. ind.	0.2	2.5	2.4	0.7	0.0	0.0	0.0	0.0	8.4	16.4
pr. met.ind.	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	8.5
other high	0.2	1.0	0.1	0.2	0.2	0.8	0.0	0.0	1.4	5.7
other low	1.2	1.3	0.3	0.4	0.3	0.4	0.5	0.4	0.5	11.4
power pl.	0.2	10.4	1.5	20.4	0.0	0.0	0.0	5.9	0.0	80.3
priv. cars	15.1	21.2	3.4	7.9	3.9	4.7	6.8	5.7	6.0	162
trucks	10.5	15.2	2.3	5.6	2.8	3.2	4.7	4.1	4.0	115
oth. traffic	2.3	3.1	0.5	1.1	0.6	0.7	1.0	0.8	0.9	26
ships	0.1	13.2	3.8	0.9	0.2	0.3	0.1	0.8	0.4	33
domestic	3.7	4.0	0.8	1.3	0.9	1.2	1.5	1.1	1.6	34
Total	37.8	91.7	16.5	38.9	8.8	11.3	14.6	19.2	24.6	523.4

Table A.7. Process emissions of SO_2 and NO_x in 1980 in 20 areas in kiloton/yr.

	SO_2						NO_x		
area	refin.	fert. ind.	other chem.	prim. metal	other high	other low	fert.	other chem	other high
1			2.6	0.8	0.2	0.1		0.6	0.6
2						0.1			
3			0.3		0.2	0.1			0.1
4						0.1			
5			2.5			0.2		0.1	
6						0.1			0.1
7						0.1			0.1
8				0.2	0.1	0.2			0.1
9						0.2			
10						0.1			
11	0.4		0.9	5.4		0.5	5.6		0.2
12					0.1	0.4		0.1	0.1
13	18	2.6	15.1		1.0	0.4	2.1	0.9	0.7
14	0.7	2.0	0.4	2.1	0.4	0.1	2.4	0.9	0.1
15			0.5		0.5			0.3	0.2
16						0.1			0.1
17						0.1			0.6
18				0.5		0.1			
19						0.1			
20			4.8		0.3	0.2	5.8	3.1	1
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Total	19	4.6	27	8.9	2.9	3.4	16	6.1	4

Table A.8. Regional distribution of SO_2-emission in the Netherlands (1980).

REGION	high sources (kton)	%	low sources (kton)	%	all sources (kton)	%
1	11.7	3.0	1.7	2.4	13.4	2.9
2	0.0	0.0	1.9	2.7	1.9	0.4
3	1.3	0.3	1.3	1.9	2.6	0.6
4	15.4	3.9	1.2	1.7	16.6	3.6
5	4.4	1.1	2.2	3.2	6.6	1.4
6	25.9	6.6	1.7	2.4	27.6	6.0
7	0.2	0.0	1.0	1.5	1.2	0.3
8	9.6	2.4	4.5	6.5	14.1	3.0
9	16.2	4.1	3.8	5.5	20.0	4.3
10	0.4	0.1	1.5	2.2	1.9	0.4
11	31.9	8.1	9.8	14.0	41.7	9.0
12	0.9	0.2	5.5	7.9	6.3	1.4
13	165.1	42.0	18.4	26.5	183.9	39.6
14	18.3	4.6	4.0	5.7	22.2	4.8
15	52.6	13.4	1.8	2.6	54.4	11.7
16	0.1	0.0	1.4	2.1	1.5	0.4
17	0.0	0.0	1.6	2.3	1.6	0.3
18	0.8	0.2	2.0	2.9	2.7	0.6
19	29.9	7.6	2.1	3.0	32.0	6.9
20	9.2	2.3	2.1	3.0	11.3	2.4
ALL	393	100	69	100	463	100

Table A.9. Regional distribution of NO_x-emission in the Netherlands (1980).

REGION	high sources (kton)	%	low sources (kton)	%	all sources (kton)	%
1	9.9	6.2	11.1	2.9	21.0	3.8
2	7.1	4.5	13.4	3.4	20.5	3.7
3	0.4	0.3	9.8	2.5	10.3	1.9
4	5.1	3.2	9.5	2.4	14.6	2.7
5	0.6	0.3	15.1	3.9	15.6	2.8
6	5.1	3.2	20.6	5.3	25.7	4.7
7	0.2	0.1	7.8	2.0	7.9	1.4
8	4.6	2.9	30.8	7.9	35.3	6.4
9	3.3	2.1	30.1	7.7	33.3	6.1
10	0.1	0.1	9.9	2.5	10.1	1.8
11	27.1	16.9	48.1	12.4	75.2	13.7
12	0.8	0.5	37.3	9.6	38.0	6.9
13	36.1	22.6	59.3	15.2	95.4	17.4
14	8.8	5.5	11.1	2.8	19.9	3.6
15	21.8	13.6	17.5	4.5	39.3	7.1
16	0.3	0.2	8.7	2.2	9.0	1.6
17	1.4	0.8	10.5	2.7	11.9	2.2
18	0.1	0.1	14.6	3.7	14.7	2.7
19	5.9	3.7	13.3	3.4	19.2	3.5
20	21.1	13.2	13.4	3.4	34.5	6.3
ALL	160	100	389	100	549	100

Table A.10 Emission of NH_3 in the 20 Dutch regions (1980, kiloton).

REGION$	CATTLE*	PIGS*	POULTRY*	SHEEP*	FERTILIZER* USE	INDUSTRY@	HUMANS*	TOTAL
1	6.5	0.5	0.8	0.7	1.0		0.4	9.9
2	20.7	0.6	1.2	1	1.7		0.4	25.6
3	9.2	1.1	1.4		1.1		0.3	13.0
4	10.7	2.0	1.2		0.8		0.3	15.0
5	11.8	5.4	1.7		0.8		0.3	20.0
6	8.6	4.2	3.2		0.3		0.6	17.0
7	10.7	6.9	1.6		0.7		0.6	20.5
8	6.7	2.2	1.4		0.5		0.6	11.3
9	7.2	2.1	0.6		0.4		0.3	10.5
10	4.2	0.2	0.3	1.4	0.4		0.9	7.3
11	3.2	0.1	0.1	0.7	0.5		0.3	4.9
12	5.0	0.9	0.3		0.3		0.5	7.0
13	4.4	0.6	0.3		0.5	2	1.5	9.6
14	1.7	0.4	0.5		0.6	2	0.2	5.2
15	4.6	2.2	0.9		0.4		0.4	8.5
16	5.0	3.2	0.9		0.4		0.5	10.0
17	7.4	6.5	2.8		0.5		0.2	17.4
18	6.3	6.3	3.4		0.4		0.3	16.7
19	2.3	3.7	2.9		0.2		0.3	9.3
20	3.9	2.4	2.7		0.3	3	0.4	12.5
TOTAL	140	51	28	4	12	7	9	251

$ REGIONAL DISTRIBUTION OF EMISSION DUE TO SHEEP, INDUSTRY AND HUMANS IN ALL YEARS THE SAME AS IN 1980

* DERIVED FROM BUIJSMAN

@ DERIVED FROM PRODUCTION AND EMISSION FACTOR

Table A.11 Distribution of NH_3-emissions over the 20 Dutch areas (1980).

REGION	Humans/ pets	Sheep	Fertil- izer	Industry	Animals
1	4	18	9		5
2	4	26	18		10
3	3		10		5
4	3		7		6
5	3		7		9
6	6		2		7
7	6		4		8
8	6		3		5
9	3		4		5
10	10	37	3		2
11	3	18	6		2
12	5		2		3
13	16		3	33	2
14	2		3	27	1
15	4		4		3
16	5		2		4
17	2		3		8
18	3		3		7
19	3		2		4
20	4		2	40	4
ALL	100	100	100	100	100

Table A.12. NO_x-emission (kiloton.yr^{-1}) from natural sources in the DAS-areas.

COUNTRY	REGION	AREA (km^2)	NO_x-EMISSION	
THE NETHERLANDS	1 - 20	40844		10
UNITED KINGDOM		244046		57
IRELAND		70283		16
	21	79000	18	
	22	157000	37	
	23	79000	18	
FRANCE		547026		128
LUXEMBOURG		2586		1
	24	165000	38	
	25	385000	90	
BELGIUM		30513		7
	26	10000	2	
	27	10000	2	
	28	10000	2	
GERMANY, FED. REP.		248577		58
	29	83000	19	
	30	83000	19	
	31	83000	19	
REGION 32				150
GERMAN DEMOCRATIC REP.		108333	25	
HUNGARY		93030	22	
POLAND		312677	73	
CZECHOSLVAKIA		127869	30	
REGION 33				1861
AUSTRIA		83849	20	
DENMARK		43069	10	
FINLAND		337009	79	
ITALY		301225	70	
NORWAY		324219	76	
PORTUGAL		92082	21	
SPAIN		504782	118	
SWEDEN		449964	105	
SWITZERLAND		41288	10	
USSR EMEP		5800000	1353	
TOTAL				2287

Table A.13. NH_3-emission (kiloton.yr^{-1}) from natural sources in the DAS-areas.

COUNTRY	REGION	AREA@ (km^2)	NH_3-EMISSION
THE NETHERLANDS	1 - 20	20000#	2
UNITED KINGDOM		183035	16
IRELAND		52712	5
	21	58937	5
	22	117873	11
	23	58937	5
FRANCE		410270	37
LUXEMBOURG		1940	0
	24	123663	11
	25	288546	26
BELGIUM		22885	2
	26	7628	1
	27	7628	1
	28	7628	1
GERMANY, FED. REP.		186433	17
	29	62144	6
	30	62144	6
	31	62144	6
	32	481432	43
GERMAN DEMOCRATIC REP.		81250	7
HUNGARY		69773	6
POLAND		234508	21
CZECHOSLVAKIA		95902	9
	33	5983115	538
AUSTRIA		62887	6
DENMARK		32302	3
FINLAND		252757	23
ITALY		225919	20
NORWAY		243164	22
PORTUGAL		69062	6
SPAIN		378587	34
SWEDEN		337473	30
SWITZERLAND		30966	3
USSR EMEP		4350000	392
TOTAL		7341820	661

@Area = area undisturbed land ≈ 75 % of total area
#Area = area undisturbed land ≈ 50 % of total area

Table A.14. VOC-emission (kiloton.yr^{-1}) from natural sources in the DAS-areas.

Country	Region	Forest area (km^2)		Temp.(^oC)	VOC-emission		
		decidious	coniferous		Baars	OECD	Estimate
Netherlands	1-20	1360	1960	9.3	14	28	
United Kingdom	21-23	15000	17000	10.7	150	71	
Ireland					n.a	17	
France	24,25	45000	70000	11.5	667*	998	
Belgium	26-28	2100	3700	9.9	28	35	
FRG	29-31	21700	48000	9.0	320	220	
D.D.R.	32	} 22000	115000	8.5	} 695		
Poland							
Czechoslowakia							
Hungary		12640	2290	13			57
USSR (Europ.part)	33						1504
Norway						180	
Sweden						750	
Finland						522	
Denmark						47	
Switzerland					} 700	45	
Austria						140	
Italy						550	
Spain						1400	
Portugal						266	

*PHOXA-part only

Table A.15. Regional distribution of low SO_2 emissions in the past.

area	%	1950	1955	1960	1965	1970	1975
1	2.3	3	5	5	8	6	3
2	2.4	4	5	6	8	7	3
3	1.7	3	3	4	6	5	2
4	1.5	2	3	4	5	4	2
5	2.8	4	6	7	10	8	3
6	2.3	3	5	5	8	6	3
7	1.5	2	3	4	5	4	2
8	6.5	10	13	15	23	18	7
9	4.8	7	10	11	17	13	5
10	2.0	3	4	5	7	6	2
11	14.3	21	29	34	51	39	16
12	8.1	12	16	19	29	22	9
13	29.1	44	58	69	103	80	33
14	6.6	10	13	16	23	18	7
15	2.2	3	4	5	8	6	2
16	2.0	3	4	5	7	6	2
17	2.1	3	4	5	7	6	2
18	2.5	4	5	6	9	7	3
19	2.7	4	5	6	10	7	3
20	2.7	4	5	6	10	7	3
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TOTAL	100	150	200	236	354	276	112

Table A.16. Regional distribution of high SO_2 emissions in the past.

area	%	1950	1955	1960	1965	1970	1975
1	3.0	11	14	17	21	16	9
2	0.0	0	0	0	0	0	0
3	0.4	1	2	2	3	2	1
4	3.7	13	18	21	26	20	11
5	1.1	4	5	6	8	6	3
6	6.2	22	30	36	44	33	19
7	0.1	0	0	1	1	1	0
8	2.3	8	11	13	16	12	7
9	3.9	14	19	23	28	21	12
10	0.1	0	0	1	1	1	0
11	7.7	28	37	45	55	41	23
12	0.3	1	1	2	2	2	1
13	43.7	157	210	253	312	233	132
14	4.9	18	24	28	35	26	15
15	12.9	46	62	75	92	69	39
16	0.0	0	0	0	0	0	0
17	0.0	0	0	0	0	0	0
18	0.2	1	1	1	1	1	1
19	7.1	26	34	41	51	38	21
20	2.4	9	12	14	17	13	7
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TOTAL	100	360	480	578	713	533	302

Table A.17. Regional distribution of high NO_x emissions in the past.

area	%	1950	1955	1960	1965	1970	1975
1	6.5	7	8	9	10	11	10
2	3.9	4	5	5	6	7	6
3	0.4	0	1	1	1	1	1
4	2.8	3	4	4	4	5	4
5	0.4	0	1	1	1	1	1
6	2.9	3	4	4	5	5	4
7	0.2	0	0	0	0	0	0
8	2.6	3	3	3	4	4	4
9	1.8	2	2	2	3	3	3
10	0.1	0	0	0	0	0	0
11	14.6	17	18	20	23	25	22
12	0.6	1	1	1	1	1	1
13	24.7	28	31	33	39	42	38
14	5.8	7	7	8	9	10	9
15	12.2	14	15	16	19	21	19
16	0.3	0	0	0	0	1	0
17	1.5	2	2	2	2	3	2
18	0.1	0	0	0	0	0	0
19	3.2	4	4	4	5	6	5
20	15.3	18	19	21	24	26	23
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TOTAL	100	115	125	134	157	172	153

Table A.18. Regional distribution of low NO_x emissions in the past.

area	%	1950	1955	1960	1965	1970	1975
1	2.9	2	3	3	5	7	7
2	3.5	2	3	4	6	8	9
3	2.6	2	2	3	5	6	7
4	2.5	2	2	3	4	6	6
5	4.0	2	4	5	7	10	10
6	5.3	3	5	6	9	13	14
7	2.0	1	2	2	4	5	5
8	7.6	5	7	9	13	18	20
9	7.7	5	7	9	14	18	20
10	2.6	2	2	3	5	6	7
11	12.7	8	11	15	22	30	33
12	9.2	6	8	11	16	22	24
13	14.7	9	13	17	26	35	38
14	2.7	2	2	3	5	6	7
15	4.5	3	4	5	8	11	12
16	2.3	1	2	3	4	5	6
17	2.7	2	2	3	5	6	7
18	3.8	2	3	4	7	9	10
19	3.4	2	3	4	6	8	9
20	3.5	2	3	4	6	8	9
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TOTAL	100	60	90	117	176	238	257

Table A.19. Ammonia emissions in 20 Dutch areas (1950).

REGION	CATTLE	PIGS	POULTRY	SHEEP	FERTIL. USE	INDUSTRY	HUMANS	TOTAL
1	3.7	0.2	0.2	0.3	0.4		0.3	5.1
2	11.8	0.4	0.2	0.5	0.4		0.3	13.5
3	5.0	0.7	0.4		0.3		0.2	6.6
4	4.7	0.4	0.2		0.3		0.2	5.8
5	4.6	0.7	0.6		0.2		0.2	6.3
6	3.6	0.6	1.3		0.2		0.4	6.1
7	4.3	0.9	1.0		0.1		0.4	6.7
8	3.5	0.6	0.4		0.2		0.4	5.0
9	4.4	0.7	0.2		0.1		0.2	5.7
10	3.2	0.2	0.2	0.6	0.1		0.6	5.0
11	3.3	0.1	0.2	0.3	0.1		0.2	4.3
12	4.6	0.7	0.2		0.1		0.4	6.0
13	4.2	0.6	0.2		0.2	0	1.1	6.5
14	1.8	0.2	0.2		0.3	0	0.1	2.9
15	2.5	0.2	0.2		0.2		0.3	3.4
16	1.9	0.2	0.2		0.1		0.4	2.8
17	2.6	0.6	0.4		0.1		0.1	3.8
18	1.9	0.4	0.4		0.1		0.2	3.0
19	0.8	0.4	0.4		0.1		0.2	1.9
20	2.4	0.6	0.6		0.2	0	0.3	4.3
TOTAL	75	9	7	2	4	1	7	105

Table A.20 Ammonia emissions in 20 Dutch areas (1955).

REGION	CATTLE	PIGS	POULTRY	SHEEP	FERTIL. USE	INDUSTRY	HUMANS	TOTAL
1	3.9	0.2	0.4	0.3	0.4		0.3	5.5
2	11.9	0.4	0.2	0.4	0.6		0.3	13.9
3	5.1	0.7	0.6		0.4		0.2	7.1
4	5.1	0.6	0.6		0.3		0.2	6.8
5	4.9	1.1	1.0		0.3		0.2	7.5
6	3.6	0.7	1.9		0.2		0.5	6.9
7	4.4	1.3	1.3		0.2		0.5	7.8
8	3.5	0.7	0.4		0.2		0.5	5.3
9	4.4	0.7	0.6		0.2		0.2	6.2
10	3.2	0.2	0.2	0.6	0.2		0.7	5.1
11	3.1	0.1	0.2	0.3	0.2		0.2	4.1
12	4.3	0.7	0.2		0.2		0.4	5.8
13	3.9	0.6	0.4		0.3	0	1.2	6.7
14	1.7	0.2	0.2		0.3	0	0.2	2.8
15	2.6	0.2	0.2		0.2		0.3	3.5
16	2.1	0.4	0.2		0.1		0.4	3.1
17	2.6	1.1	1.0		0.2		0.2	5.1
18	1.9	0.7	0.8		0.2		0.2	3.9
19	1.0	0.6	0.6		0.1		0.2	2.4
20	2.5	0.7	0.6		0.2	0	0.3	4.8
TOTAL	76	12	11	2	5	1	7	114

Table A.21. Ammonia emissions in 20 Dutch areas (1960).

REGION	CATTLE	PIGS	POULTRY	SHEEP	FERTIL. USE	INDUSTRY	HUMANS	TOTAL
1	4.0	0.2	0.2	0.4	0.5		0.3	5.6
2	12.8	0.4	0.4	0.5	0.6		0.3	15.0
3	6.0	0.7	0.6		0.5		0.2	8.0
4	6.0	0.6	0.6		0.4		0.2	7.8
5	5.6	1.3	1.2		0.3		0.2	8.6
6	4.0	0.9	2.7		0.2		0.5	8.3
7	5.3	1.7	1.7		0.2		0.5	9.4
8	4.0	0.7	0.6		0.3		0.5	6.1
9	4.9	0.9	0.6		0.2		0.2	6.8
10	3.5	0.2	0.2	0.7	0.2		0.7	5.5
11	3.2	0.1	0.4	0.4	0.2		0.2	4.5
12	4.4	0.7	0.2		0.3		0.4	6.1
13	4.2	0.6	0.4		0.3	1	1.2	7.3
14	1.9	0.2	0.2		0.2	1	0.2	3.2
15	3.1	0.4	0.2		0.2		0.3	4.1
16	2.5	0.4	0.4		0.2		0.4	3.9
17	3.2	1.5	1.2		0.2		0.2	6.2
18	2.4	0.9	1.2		0.2		0.2	4.9
19	1.1	0.9	1.0		0.1		0.2	3.4
20	2.9	0.7	1.0		0.2	1	0.3	6.0
TOTAL	85	14	15	2	6	2	8	131

Table A.22. Ammonia emissions in 20 Dutch areas (1965).

REGION	CATTLE	PIGS	POULTRY	SHEEP	FERTIL. USE	INDUSTRY	HUMANS	TOTAL
1	4.3	0.2	0.2	0.4	0.7		0.3	6.1
2	13.1	0.2	0.6	0.6	1.1		0.3	15.8
3	6.5	0.7	0.4		0.8		0.3	8.7
4	6.7	0.7	0.6		0.6		0.3	8.8
5	6.2	2.1	1.2		0.6		0.3	10.3
6	4.6	1.3	2.7		0.4		0.5	9.5
7	5.8	2.6	1.5		0.4		0.5	10.9
8	4.2	0.9	0.6		0.5		0.5	6.7
9	4.9	1.1	0.6		0.1		0.3	6.9
10	3.3	0.2	0.2	0.8	0.4		0.8	5.7
11	2.8	0.1	0.2	0.4	0.4		0.3	4.2
12	4.0	0.7	0.2		0.3		0.4	5.7
13	3.7	0.6	0.2		0.5	1	1.3	7.2
14	1.8	0.2	0.2		0.4	1	0.2	3.5
15	3.2	0.6	0.4		0.4		0.3	4.9
16	2.8	0.7	0.4		0.3		0.4	4.6
17	3.9	1.7	1.3		0.5		0.2	7.6
18	3.1	1.5	1.2		0.3		0.3	6.3
19	1.2	1.3	1.3		0.2		0.3	4.4
20	2.9	0.9	1.0		0.3	1	0.3	6.6
TOTAL	89	18	15	2	9	3	8	144

Table A.23. Ammonia emissions in 20 Dutch areas (1970).

REGION	CATTLE	PIGS	POULTRY	SHEEP	FERTIL. USE	INDUSTRY	HUMANS	TOTAL
1	4.9	0.4	0.4	0.5	0.9		0.4	7.4
2	14.3	0.4	0.8	0.7	1.5		0.4	18.0
3	7.1	0.9	0.8		1.0		0.3	10.1
4	7.5	1.3	0.8		0.8		0.3	10.7
5	7.4	3.2	1.3		0.8		0.3	13.0
6	5.8	2.2	2.5		0.5		0.6	11.6
7	6.8	4.1	1.3		0.6		0.6	13.4
8	4.7	1.5	0.8		0.6		0.6	8.1
9	5.3	1.7	0.6		0.5		0.3	8.3
10	3.5	0.2	0.2	0.9	0.5		0.8	6.1
11	2.8	0.1	0.2	0.5	0.5		0.3	4.3
12	4.2	0.7	0.3		0.4		0.5	6.1
13	5.1	0.6	0.3		0.6	2	1.4	9.6
14	1.8	0.4	0.2		0.6	1	0.2	4.4
15	3.6	1.3	0.6		0.4		0.4	6.3
16	3.1	1.7	0.6		0.4		0.5	6.2
17	4.6	3.6	1.7		0.5		0.2	10.5
18	3.7	3.0	1.9		0.4		0.3	9.3
19	1.5	2.2	1.9		0.3		0.3	6.3
20	3.1	1.7	1.9		0.4	2	0.4	9.3
TOTAL	101	31	19	3	12	5	9	179

Table A.24 Ammonia emissions in 20 Dutch areas (1975).

REGION	CATTLE	PIGS	POULTRY	SHEEP	FERTIL. USE	INDUSTRY	HUMANS	TOTAL
1	6.5	0.4	0.4	0.6	0.9		0.4	9.2
2	19.1	0.6	1.0	0.9	1.5		0.4	23.4
3	9.3	0.9	1.0		1.0		0.3	12.5
4	10.1	1.3	1.0		0.8		0.3	13.5
5	10.6	3.9	1.5		0.8		0.3	17.2
6	7.8	3.0	2.3		0.5		0.6	14.2
7	9.8	5.2	1.3		0.6		0.6	17.6
8	6.4	1.9	1.0		0.6		0.6	10.4
9	6.9	1.9	0.6		0.5		0.3	10.1
10	4.4	0.2	0.4	1.2	0.5		0.9	7.6
11	3.3	0.1	0.2	0.6	0.5		0.3	5.0
12	5.1	0.7	0.3		0.4		0.5	7.0
13	4.4	0.6	0.3		0.6	2	1.4	9.0
14	2.0	0.4	0.5		0.6	1	0.2	4.9
15	4.6	1.9	0.9		0.4		0.4	8.1
16	4.9	2.4	0.8		0.4		0.5	9.0
17	6.7	4.9	2.3		0.5		0.2	14.6
18	5.7	4.3	2.7		0.4		0.3	13.4
19	2.1	2.6	2.3		0.3		0.3	7.6
20	3.8	1.9	2.3		0.4	2	0.4	10.7
TOTAL	133	39	23	3	12	5	9	225

Table A.25. Estimation of SO_2- and NO_x emission data for the period 1950 - 1975.

As much as possible officially published data are used. When no data could be retrieved from literature the following procedure has been applied:

1 An inventory was made of the energy consumption (solid, liquid and gaseous fuels) of the respective countries in the years of interest. These data were derived from UN-statistics:

ENERGY CONSUMPTION SOLID FUELS IN MTOE

region	1950	1955	1960	1965	1970	1975
Ireland	2.75	2.77	2.51	2.24	2.66	1.47
United Kingdom	140.52	153.82	138.37	130.31	108.25	77.10
21	31.52	34.45	30.99	29.16	24.40	17.28
22 (incl. Ireland)	95.99	104.92	94.39	88.81	74.31	52.64
23	15.76	17.22	15.50	14.58	12.20	8.64
France	44.65	48.03	48.41	47.72	39.69	27.62
24 (incl. Luxemb)	28.70	31.33	23.90	31.17	26.32	18.45
25	17.86	19.21	19.36	19.09	15.87	11.05
Luxembourg	1.91	2.51	2.85	2.54	2.51	1.88
Belgium	18.01	20.34	17.99	16.45	13.82	9.33
26	4.38	5.03	4.59	4.18	3.59	2.47
27	9.96	11.42	10.42	9.50	8.16	5.60
28	3.67	3.89	2.99	1.78	2.06	1.26
FRG	83.52	112.85	111.17	104.27	93.77	73.88
29	17.54	23.70	23.35	21.90	19.69	15.51
30	38.42	51.91	51.14	47.96	43.13	33.98
31	27.56	37.24	36.69	34.41	30.94	24.38
Czechoslowakia	25.00	32.96	41.96	50.12	53.69	43.16
GDR	33.88	48.48	54.60	61.05	62.16	57.95
Hungary	5.32	9.82	12.10	15.25	13.27	9.52
Poland	35.61	48.17	61.27	71.41	83.73	99.12
Austria	5.22	5.86	5.49	5.40	4.66	3.72
Denmark	4.42	4.75	3.90	3.57	2.56	2.86
Finland	1.34	1.88	2.09	2.03	2.47	2.36
Italy	6.73	8.01	7.71	8.45	9.77	8.06
Norway	1.21	1.00	0.82	0.91	1.03	0.90
Portugal	0.90	0.63	0.66	0.88	0.82	0.45
Spain	8.65	9.69	10.45	10.53	10.89	11.11
Sweden	5.01	4.14	2.83	2.20	1.91	1.88
Switzerland	1.79	1.83	1.81	1.17	0.57	0.20
USSR (incl.asiat.)	159.46	234.92	268.91	287.79	300.85	333.24

ENERGY CONSUMPTION LIQUID FUELS IN MTOE

regio	1950	1955	1960	1965	1970	1975
Ireland	0.57	1.04	1.05	2.20	3.76	4.43
United Kingdom	14.07	22.24	40.31	61.09	86.27	78.79
21	3.22	5.12	9.10	13.92	19.81	18.31
22 (incl. Ireland)	9.81	15.60	27.71	42.40	60.32	55.76
23	1.61	2.56	4.55	6.96	9.90	9.15
France	9.61	16.12	24.60	48.86	86.45	87.88
24 (incl. Luxemb)	5.35	9.00	13.76	27.73	48.96	49.57
25	4.33	7.25	11.07	21.99	38.90	39.55
Luxembourg	0.06	0.13	0.23	0.86	1.41	1.24
Belgium	2.20	4.15	6.53	12.40	20.84	19.35
26	0.50	0.94	1.49	2.92	4.89	4.53
27	1.13	2.14	3.38	6.63	11.12	10.29
28	0.57	1.07	1.66	2.85	4.82	4.52
FRG	2.68	9.90	29.85	71.69	118.02	112.26
29	0.56	2.08	6.27	15.06	24.78	23.57
30	1.23	4.55	13.73	32.98	54.29	51.64
31	0.88	3.27	9.85	23.66	38.95	37.05
Czechoslowakia	0.72	1.09	1.82	5.18	8.76	14.26
GDR	0.19	0.68	1.37	3.51	8.74	14.07
Hungary	0.69	1.30	1.83	3.30	5.82	8.79
Poland	0.40	1.26	2.21	4.38	7.56	10.90
Austria	0.53	2.20	2.78	5.36	8.81	9.50
Denmark	1.64	3.08	5.16	10.08	17.53	13.95
Finland	0.51	1.35	2.16	5.74	9.82	10.27
Italy	4.46	10.07	19.87	43.78	78.69	81.61
Norway	1.30	2.54	3.28	4.30	7.26	6.70
Portugal	0.62	1.00	1.43	2.05	3.24	5.35
Spain	1.17	3.18	4.35	10.72	22.45	38.34
Sweden	3.64	8.00	13.26	18.64	30.35	23.38
Switzerland	1.00	1.98	3.73	7.93	12.50	11.27
USSR (incl.asiat.)	34.91	63.67	110.52	171.79	255.63	313.35

ENERGY CONSUMPTION NATURAL GAS IN MTOE

region	1950	1955	1960	1965	1970	1975
Ireland	0.00	0.00	0.00	0.00	0.00	0.00
United Kingdom	0.00	0.03	0.08	0.78	11.24	34.66
21	0.00	0.01	0.02	0.17	2.47	7.62
22 (incl. Ireland)	0.00	0.02	0.05	0.52	7.53	23.22
23	0.00	0.00	0.01	0.09	1.24	3.81
France	0.21	0.24	2.66	4.69	9.30	17.50
24 (incl. Luxemb.)	0.13	0.14	1.59	2.81	5.59	10.88
25	0.08	0.10	1.06	1.88	3.72	7.00
Luxembourg	0.00	0.00	0.00	0.00	0.01	0.38

Belgium	0.06	0.15	0.13	0.15	4.25	9.06
26	0.01	0.03	0.03	0.03	0.94	2.08
27	0.03	0.07	0.07	0.08	2.13	4.72
28	0.02	0.04	0.04	0.04	1.19	2.26
FRG	0.08	0.58	0.86	3.20	15.57	38.21
29	0.02	0.12	0.18	0.67	3.27	8.02
30	0.04	0.26	0.40	1.47	7.16	17.57
31	0.03	0.19	0.28	1.06	5.14	12.61
Czechoslowakia	0.03	0.16	1.34	0.90	2.37	3.55
GDR	0.00	0.00	0.02	0.12	1.15	4.91
Hungary	0.35	0.51	0.49	1.19	3.42	4.89
Poland	0.21	0.49	0.74	1.64	5.77	7.06
Austria	0.09	0.70	1.37	1.61	2.80	4.02
Denmark	0.00	0.00	0.00	0.00	0.00	0.00
Finland	0.00	0.00	0.00	0.00	0.00	0.69
Italy	0.48	3.38	6.01	7.27	12.04	20.24
Norway	0.00	0.00	0.00	0.00	0.00	0.19
Portugal	0.00	0.00	0.00	0.00	0.00	0.00
Spain	0.00	0.00	0.00	0.00	0.10	1.23
Sweden	0.00	0.00	0.00	0.00	0.00	0.00
Switzerland	0.00	0.00	0.00	0.00	0.01	0.58
USSR	5.32	8.23	42.01	118.67	184.80	230.01

2 For each country/fuel type emission factors were estimated; as a starting point emission factors from CBS and TNO were used.

3 The emission factors were modified - when necessary and possible - by fitting the calculated emission data to the published emission data. The result of this procedure is shown in the next table:

Emission factors for combustion of fuel (ton/PJ)

	SO_2			NO_x		
	solid	liquid	gas	solid	liquid	gas
United Kingdom*	645	955	0	285	190	120
France	430	595	0	355	285	190
Belgium	475	715	0	285	165	120
FRG	455	380	0	285	330	190
Other Western European countries	380	715	0	310	240	120
Eastern European countries	955	955	0	240	145	120

*Including process emissions

4 Process emissions were taken into account by assuming that the ratio process emission/combustion emission has been constant in the period 1950-1975 (next table):

Ratio process emission/combustion emission.

	SO_2	NO_x
France	0,15	0,02
Belgium	0,07	0,07
FRG	0,02	0,02
Region 33	0,2	0,05
Region 32	0,1	0,05

5 The regional distribution of the emissions (for the regions 21 - 31) was assumed to be constant in the period 1950-1980.

6 The ratio high emission/low emission was assumed to be constant for SO_2, the ratio for NO_x was assumed to be higher in the past:

% NO_x emitted from LOW sources

REGION	1950-1960	1965	1970	1975
21	50	55	60	65
22	33	38	43	48
23	54	59	64	69
24-31	44	49	54	59
32/33	40	40	40	45
Netherlands	47	53	58	63

Table A.26a NH_3 emissions in 1950 in the other countries (kiloton).

1950	ANIMALS	FERTIL. USE	FERTIL. IND.	INHABI- TANTS	TOTAL
AUSTRIA	81	1	0	4	87
BELGIUM	63	2	1	4	69
CZECHOSLOVAKIA	152	2	1	8	164
DDR	146	10	0	12	168
DENMARK	113	5	0	3	121
FINLAND	63	0	0	3	66
FRANCE	527	16	1	27	571
FRG	403	8	2	33	446
HUNGARY	110	0	0	6	116
IRELAND	0	0	0	2	2
ITALY	334	16	1	30	381
NORWAY	48	2	1	2	53
POLAND	303	5	0	16	324
PORTUGAL	54	2	0	5	62
SPAIN	198	3	0	18	220
SWEDEN	90	2	0	5	96
SWITZERLAND	51	0	0	3	54
UNITED KINGDOM	470	16	1	33	520
EUROPEAN RUSSIA	817	0	0	101	917

Table A.26b NH_3 emissions in 1955 in the other countries (kiloton).

1955	ANIMALS	FERTIL. USE	FERTIL. INDUST.	INHABI- TANTS	TOTAL
AUSTRIA	81	2	1	5	88
BELGIUM	64	2	1	5	72
CZECHOSLOVAKIA	147	0	2	8	157
DDR	160	13	0	12	185
DENMARK	113	5	0	3	121
FINLAND	67	1	0	3	70
FRANCE	585	23	2	29	639
FRG	395	11	4	34	444
HUNGARY	105	0	0	6	111
IRELAND	0	0	0	2	2
ITALY	322	26	2	32	381
NORWAY	44	2	1	2	49
POLAND	320	0	1	18	339
PORTUGAL	50	2	0	6	58
SPAIN	176	10	0	19	205
SWEDEN	82	2	0	5	89
SWITZERLAND	50	1	0	3	54
UNITED KINGDOM	463	22	2	33	520
EUROPEAN RUSSIA	806	0	1	109	916

Table A.26c NH_3 emissions in 1960 in the other countries (kiloton).

1960	ANIMALS	FERTIL. USE	FERTIL. INDUST.	INHABI-TANTS	TOTAL
AUSTRIA	78	2	1	5	85
BELGIUM	71	2	1	6	80
CZECHOSLOVAKIA	148	11	2	9	170
DDR	176	18	0	11	204
DENMARK	118	7	0	3	129
FINLAND	56	1	0	3	60
FRANCE	577	34	3	30	644
FRG	415	14	6	36	4471
GREAT BRITTAIN	0	0	0	0	0
HUNGARY	98	6	0	7	111
IRELAND	0	0	0	2	2
ITALY	325	34	3	33	395
NORWAY	39	4	1	2	47
POLAND	341	21	1	19	384
PORTUGAL	49	4	0	6	58
SPAIN	234	15	1	20	269
SWEDEN	73	3	0	5	81
SWITZERLAND	53	1	0	4	58
UNITED KINGDOM	492	33	2	34	562
EUROPEAN RUSSIA	1019	37	2	120	1177

Table A.26d NH_3 emissions in 1965 in the other countries (kiloton).

1965	ANIMALS	FERT. USE	FERT. INDUST.	INHABI-TANTS	TOTAL
AUSTRIA	77	6	1	5	88
BELGIUM	74	3	2	6	84
CZECHOSLOVAKIA	147	16	2	9	173
DDR	178	24	0	11	214
DENMARK	125	12	1	3	140
FINLAND	59	2	1	3	64
FRANCE	630	53	5	31	720
FRG	448	20	7	38	512
HUNGARY	112	16	1	7	135
IRELAND	0	1	0	2	3
ITALY	330	48	5	34	416
NORWAY	40	4	2	2	47
POLAND	375	26	2	20	424
PORTUGAL	49	5	1	6	60
SPAIN	207	21	2	21	250
SWEDEN	68	5	1	5	78
SWITZERLAND	55	1	0	4	60
UNITED KINGDOM	531	51	3	35	621
EUROPEAN RUSSIA	1113	68	5	126	1312

Table A.26e NH_3 emissions in 1970 in the other countries (kiloton).

1970	ANIMALS	FERTIL. USE	FERTIL. INDUST.	INHABI-TANTS	TOTAL
AUSTRIA	81	7	1	5	94
BELGIUM	84	3	3	6	96
CZECHOSLOVAKIA	148	24	2	9	184
DDR	191	29	0	11	231
DENMARK	111	17	1	3	132
FINLAND	56	3	1	3	63
FRANCE	702	89	7	33	831
FRG	475	26	8	39	547
HUNGARY	110	31	2	7	149
IRELAND	0	1	0	2	4
ITALY	355	59	5	35	454
NORWAY	36	5	2	3	45
POLAND	401	49	5	21	476
PORTUGAL	51	5	1	6	62
SPAIN	232	32	3	22	288
SWEDEN	62	6	1	5	73
SWITZERLAND	59	3	0	4	66
UNITED KINGDOM	549	58	4	36	647
EUROPEAN RUSSIA	1200	117	11	135	1463

Table A.26f NH_3 emissions in 1975 in the other countries (kiloton).

1975	ANIMALS	FERTIL. USE	FERTIL. INDUST.	INHABI-TANTS	TOTAL
AUSTRIA	90	7	11	5	113
BELGIUM	98	4	3	6	110
CZECHOSLOVAKIA	173	31	3	10	216
DDR	228	38	0	11	277
DENMARK	123	21	1	3	148
FINLAND	60	4	1	3	68
FRANCE	842	103	7	35	986
FRG	525	25	6	40	597
HUNGARY	123	42	2	7	174
IRELAND	0	3	1	2	5
ITALY	348	71	5	36	461
NORWAY	38	6	2	3	48
POLAND	539	73	8	22	641
PORTUGAL	56	6	1	6	68
SPAIN	252	39	4	23	318
SWEDEN	68	7	1	5	80
SWITZERLAND	68	3	0	4	74
UNITED KINGDOM	672	75	5	36	789
EUROPEAN RUSSIA	1497	189	17	141	1844

Table A.26g NH_3 emissions in 1980 in the other countries (kiloton).

1980	ANIMALS	FERTIL. USE	FERTIL. IND.	INHABI-TANTS	TOTAL
AUSTRIA	94	9	2	5	110
BELGIUM	115	4	4	6	129
CZECHOSLOVAKIA	190	39	5	10	244
DDR	233	42	1	11	287
DENMARK	129	23	1	3	156
FINLAND	58	4	1	3	67
FRANCE	852	130	8	35	1025
FRG	492	35	7	40	575
HUNGARY	129	42	3	7	181
IRELAND	0	5	1	2	8
ITALY	365	101	7	37	510
NORWAY	40	7	2	3	52
POLAND	811	80	6	23	921
PORTUGAL	55	7	1	6	70
SPAIN	262	49	5	24	340
SWEDEN	75	6	1	5	87
SWITZERLAND	70	4	0	4	79
UNITED KINGDOM	624	90	6	36	765
EUROPEAN RUSSIA	1546	211	20	148	1925

Table A.26h NH_3 emissions in the other countries (kiloton).

REGION	EMISSION					
	1950	1955	1960	1965	1970	1975
UNITED KINGDOM	522	522	564	623	650	795
FRANCE	571	639	644	720	831	986
BELGIUM	69	72	80	84	96	110
FRG	446	444	471	512	547	597
REGION 32	772	792	869	946	1040	1308
REGION 33	2056	2031	2360	2517	2740	3223

Annex A.27. VOC-emissions in the foreign areas (1950-1975).

Data on the amount of VOC emitted due to solvent use, industrial processes, and gasoline distribution in the regions 21 - 33 have been derived from Baars (1987). In this report data are given for 14 of the 20 countries. The equivalent data for the remaining 6 countries (Ireland, Hungary, Finland, Portugal, Spain, and USSR (European Part)) have been estimated on basis of the number of inhabitants in the past. It has been assumed, that the emission pro capita was the same as in comparable countries.

Data on the amount of VOC from natural sources (cf Annex A.14) has also been derived from Baars (1987). The data for the 6 remaining countries mentioned above, except for the USSR, have been derived from OECD (1988) and PHOXA (1987). It has been assumed, that the emission of VOC in the USSR is twice as high as in region 32.

Data on the amount of VOC emitted due to combustion of fossil fuels in stationary and mobile sources have been estimated using the same energy data as for SO_2 and NO_x (cf. Annex A.25) and VOC-emission factors.
The following emission factors have been used:

STATIONARY SOURCES (ton VOC/PJ):

All countries	1950-1975
Brown coal	120
Hard coal	30
Liquid fuels	10
Gaseous fuels	5

MOBILE SOURCES (kg VOC/ton fuel):

		1950-1965	1970	1975
Western Europe	gasoline	55	37	31
	diesel oil	13	12	12
	LPG	41	32	27
Eastern Europe	gasoline	79	53	44
	diesel oil	17	16	15
	LPG	41	32	27

In 1988 VOC-emission data for the year 1980 were reported by the OECD. These data, which have been provided by the member countries themselves, differed to some extent from the 1980-data calculated by the method described above. In order to have consistent data for the years 1950 - 1980, the 1950-1975 data were adapted to the 1980-OECD-data.

Annex A.28. Data for future agricultural activities in The Netherlands.

NUMBER OF ANIMALS (million)

	1986	2010-A	2010-E
Cattle	4.44	3.32	3.32
Pigs	13.48	12.94	12.94
Poultry	92.33	98.77	98.77
Calves	0.69	0.46	0.46

PRODUCTION OF N IN MANURE (kiloton)

	1986	2010-A	2010-E
Cattle	340	322	322
Pigs	131	127	118
Poultry	43	46	43
Calves	7	5	5

AMOUNT OF N IN SURPLUS MANURE (kiloton)

	1986	2010-A	2010-E
Cattle	0	0	194
Pigs	0	83	116
Poultry	0	23	42
Calves	0	2	5

APPLICATION OF MANURE (%)

	1986	2010-A	2010-E
By ploughing < 36 h	0	100	0#
By injection (grass only)	0	20	60 #

N CONTENT OF MANURE ($gr.kg^{-1}$)

	1986	2010-A	2010-E
Cattle	4.84	4.84	4.84
Pigs	6.64	5.94	5.52
Poultry	18.08	15.86	14.83
Calves	3.34	3.34	3.34

N-EMISSION FROM MANURE IN STABLE (%)

	1986	2010-A	2010-E
Cattle	7.4	7.4	7.4
Pigs	16.0	14.4	1.5
Poultry	29.5	19.9	2.0
Calves	12.0	12.0	1.3

In 2010-E all manure is processed to fertilizer.

ANNEX B

Table B.1 Emission factors[1] for SO_2 (1% sulphur content), sulphur content per fuel type per activity and NO_x-emission factors: West Germany.

SO_2 emission factor 1% sulphur content		solid	oil	gas
($ton.PJ^{-1}$)	:	650	455	455
(ton/MTOE)	:	27.24	19.07	19.07

	sulphur content (percentages)			NO_x-emission factor (gr/GJ)		
	solid	oil	gas	solid	oil	gas
1.basic ind.	1.0	1.0	0.1	285	125	125
2.chemical ind.	1.0	1.5	0.03	285	195	100
3.metal prod. ind.	1.0	1.5	0.001	285	125	125
4.other ind.	0.8	1.5	0.001	285	125	80
5.construction	0.8	0.3	0.001	285	125	55
6.private cars (petrol and lpg)		0.015			935	
7.other road traffic		0.25			1360	
8.railway	1.0	0.33		180	1150	
9.shipping (interior)		1.5			760	
10.air		0.015			250	
11.agriculture	1.0	0.8	0.001	180	1150	114
12.services/governm.	1.0	0.3	0.001	180	60	75
13.households	0.9	0.3	0.001	75	60	55
14.private cars (diesel)		0.33			350	
15.electricity gen.	0.95	1.5	0.001	330	280	110
16.refineries	0.80	2.0	0.3	300	210	120

1) emission factors for the base year 1980. Emission factors remain constant over the period 1980-2030. Abatement measures are included in abatement indices.

Table B.2 Emission factors[1] for SO_2 (1 % sulphur content), sulphur content per fuel type per activity and NO_x-emission factors: France.

SO_2 emission factor 1% sulphur content		solid	oil	gas
($ton.PJ^{-1}$)	:	650	455	455
(ton/MTOE)	:	27.24	19.07	19.07

	sulphur content (percentages)			NO_x-emission factor (gr/GJ)		
	solid	oil	gas	solid	oil	gas
1.basic ind.	1.0	2.6	0.1	180	83	125
2.chemical ind.	1.0	2.6	0.03	180	125	100
3.metal prod. ind.	1.0	2.6	0.001	180	83	125
4.other ind.	0.85	2.6	0.001	180	83	80
5.construction	0.85	0.52	0.001	180	83	55
6.private cars (petrol and lpg)		0.015			795	
7.other road traffic		0.52			1020	
8.railway	1.0	0.52		180	1150	
9.shipping (interior)		1.5			760	
10.air		0.015			250	
11.agriculture	1.0	0.8	0.001	180	1150	
12.services/governm.	1.0	0.6	0.001	180	60	75
13.households	0.9	0.6	0.001	75	60	55
14.private cars (diesel)		0.52			350	
15.electricity gen.	0.75	3.4	0.001	215	180	110
16.refineries	1.0	4.0	0.3	300	210	120

1) emission factors for the base year 1980. Emission factors remain constant over the period 1980-2030. Abatement measures are included in abatement indices.

Table B.3. Emission factors[1)] for SO_2 (1 % sulphur content), sulphur content per fuel type per activity and NO_x-emission factors: Belgium.

SO_2 emission factor 1 % sulphur content		solid	oil	gas
$(ton.PJ^{-1})$	:	650	455	455
(ton/MTOE)	:	27.24	19.07	19.07

	sulphur content (percentages)			NO_x-emission factor (gr/GJ)		
	solid	oil	gas	solid	oil	gas
1.basic ind.	1.0	2.2	0.1	180	83	125
2.chemical ind.	1.0	2.2	0.03	180	80	100
3.metal prod. ind.	1.0	2.2	0.001	180	83	125
4.other ind.	0.8	2.2	0.001	180	83	80
5.construction	0.8	0.3	0.001	180	83	55
6.private cars (petrol and lpg)		0.015			935	
7.other road traffic		0.25			1360	
8.railway	1.0	0.33		180	1150	
9.shipping (interior)		1.5			760	
10.air		0.015			250	
11.agriculture	1.0	0.7	0.001	180	350	114
12.services/governm.	1.0	0.7	0.001	180	60	75
13.households	0.9	0.7	0.001	75	60	55
14.private cars (diesel)		0.33			350	
15.electricity gen.	1.0	3.0	0.001	280	120	110
16.refineries	1.0	1.3	0.3	280	120	120

1) emission factors for the base year 1980. Emission factors remain constant over the period 1980-2030. Abatement measures are included in abatement indices.

Table B.4. Emission factors[1)] for SO_2 (1 % sulphur content), sulphur content per fuel type per activity and NO_x-emission factors: United Kingdom.

SO_2 emission factor 1% sulphur content		solid	oil	gas
($ton.PJ^{-1}$)	:	650	455	455
(ton/MTOE)	:	27.24	19.07	19.07

	sulphur content			NO_x-emission factor		
	solid	oil	gas	solid	oil	gas
	(percentages)			(gr/GJ)		
1.basic ind.	1.5	2.6	0.1	180	83	125
2.chemical ind.	1.5	2.6	0.03	180	125	100
3.metal prod. ind.	1.5	2.6	0.001	180	83	125
4.other ind.	1.5	2.6	0.001	180	83	80
5.construction	1.5	0.3	0.001	180	83	55
6.private cars (petrol and lpg)		0.015			450	
7.other road traffic		0.25			800	
8.railway	1.5	0.33		180	1150	
9.shipping (interior)		1.5			760	
10.air		0.015			250	
11.agriculture	1.5	0.8	0.001	50	50	50
12.services/governm.	1.5	0.6	0.001	50	50	50
13.households	1.5	0.6	0.001	50	50	50
14.private cars (diesel)		0.33			350	
15.electricity gen.	1.61	3.0	0.001	330	280	110
16.refineries	1.5	2.1	0.3	150	105	60

1) emission factors for the base year 1980. Emission factors remain constant over the period 1980-2030. Abatement measures are included in abatement indices.

Table B.5. Abatement indices for SO_2 and NO_x acoording to the EMAC-model for 1990-2030 (1980=1.00): West Germany

	SO_2 solid and oil 1990	2000	2010	2020	2030
1.basic ind.	0.8	0.5	same values as in 2000 for all activities		
2.chemical ind.	0.8	0.5			
3.metal prod. ind.	0.8	0.5			
4.other ind.	0.8	0.5			
5.construction	1	1			
6.private cars petrol,lpg	1	1			
7.other road traffic	1	1			
8.railway	1	1			
9.shipping (interior)	1	1			
10.air	1	1			
11.agriculture	1	1			
12.services/governm.	1	0.65			
13.households	1	0.65			
14.private cars diesel	1	1			
15.electricity gen.	0.15	0.1			
16.refineries	0.8	0.6			

	NO_x solid oil and gas 1990	2000	2010	2020	2030
1.basic ind.	1	0.65	0.6	same values as 2010 for all activities	
2.chemical ind.	1	0.65	0.6		
3.metal prod. ind.	1	0.65	0.6		
4.other ind.	1	0.65	0.6		
5.construction	1	1	0.9		
6.private cars petrol,lpg	0.7	0.4	0.4		
7.other road traffic	1	1	1		
8.railway	1	1	1		
9.shipping (interior)	1	1	1		
10.air	1	1	1		
11.agriculture	1	1	1		
12.services/governm.	1	0.75	0.75		
13.households	1	0.75	0.75		
14.private cars diesel	1	1	1		
15.electricity gen.	0.8	0.25	0.25		
16.refineries	1	0.8	0.8		

Table B.6. Abatement indices for SO_2 and NO_x acoording to the EMAC-model for 1990-2030 (1980=1.00): France.

	SO_2 solid and oil 1990	2000	2010	2020	2030
1.basic ind.	1	1	same values as 2000		
2.chemical ind.	1	1	for all activities		
3.metal prod. ind.	1	1			
4.other ind.	1	1			
5.construction	1	1			
6.private cars petrol,lpg	1	1			
7.other road traffic	1	1			
8.railway	1	1			
9.shipping (interior)	1	1			
10.air	1	1			
11.agriculture	1	1			
12.services/governm.	1	1			
13.households	1	1			
14.private cars diesel	1	1			
15.electricity gen.	0.8	0.8			
16.refineries	1	1			

	NO_x solid oil and gas 1990	2000	2010	2020	2030
1.basic ind.	1	1	same values as 2000		
2.chemical ind.	1	1	for all activities		
3.metal prod. ind.	1	1			
4.other ind.	1	1			
5.construction	1	1			
6.private cars petrol,lpg	0.8	0.4			
7.other road traffic	1	1			
8.railway	1	1			
9.shipping (interior)	1	1			
10.air	1	1			
11.agriculture	1	1			
12.services/governm.	1	1			
13.households	1	1			
14.private cars diesel	1	1			
15.electricity gen.	1	1			
16.refineries	1	1			

Table B.7. Abatement indices for SO_2 and NO_x acoording to the EMAC-model for 1990-2030 (1980=1.00): Belgium.

	SO_2 solid and oil 1990	2000	2010	2020	2030
1.basic ind.	0.9	0.8	same values as 2000 for all activities		
2.chemical ind.	0.9	0.8			
3.metal prod. ind.	0.9	0.8			
4.other ind.	0.9	0.8			
5.construction	1	1			
6.private cars petrol,lpg	1	1			
7.other road traffic	1	1			
8.railway	1	1			
9.shipping (interior)	1	1			
10.air	1	1			
11.agriculture	1	1			
12.services/governm.	1	1			
13.households	1	1			
14.private cars diesel	1	1			
15.electricity gen.	0.8	0.8			
16.refineries	0.8	0.8			

	NO_x solid oil and gas 1990	2000	2010	2020	2030
1.basic ind.	1	1	same values as 2000 for all activities		
2.chemical ind.	1	1			
3.metal prod. ind.	1	1			
4.other ind.	1	1			
5.construction	1	1			
6.private cars petrol,lpg	0.7	0.4			
7.other road traffic	1	1			
8.railway	1	1			
9.shipping (interior)	1	1			
10.air	1	1			
11.agriculture	1	1			
12.services/governm.	1	1			
13.households	1	1			
14.private cars diesel	1	1			
15.electricity gen.	1	1			
16.refineries	1	1			

Table B.8. Abatement indices for SO_2 and NO_x acoording to the EMAC-model for 1990-2030 (1980=1.00): United Kingdom.

	SO_2 solid and oil 1990	2000	2010	2020	2030
1.basic ind.	1	1	same values as 2000		
2.chemical ind.	1	1	for all activities		
3.metal prod. ind.	1	1			
4.other ind.	1	1			
5.construction	1	1			
6.private cars petrol,lpg	1	1			
7.other road traffic	1	1			
8.railway	1	1			
9.shipping (interior)	1	1			
10.air	1	1			
11.agriculture	1	1			
12.services/governm.	1	1			
13.households	1	1			
14.private cars diesel	1	1			
15.electricity gen.	0.8	0.55			
16.refineries	0.8	0.8			

	NO_x solid oil and gas 1990	2000	2010	2020	2030
1.basic ind.	1	1	same values as 2000		
2.chemical ind.	1	1	for all activities		
3.metal prod. ind.	1	1			
4.other ind.	1	1			
5.construction	1	1			
6.private cars petrol,lpg	0.7	0.4			
7.other road traffic	1	1			
8.railway	1	1			
9.shipping (interior)	1	1			
10.air	1	1			
11.agriculture	1	1			
12.services/governm.	1	1			
13.households	1	1			
14.private cars diesel	1	1			
15.electricity gen.	1	1			
16.refineries	1	1			

Table B.9 EMAC-results for SO_2-emissions per country per activity, 1980-2030: West Germany.

	1980	1990	2000	2010	2020	2030
industry						
1. basic industry	472	330	197	233	254	281
2. chemical ind.	115	60	36	49	54	60
3. metal prod. ind.	60	39	28	38	43	47
4. other ind.	271	193	137	156	172	190
5. construction	0	0	0	0	0	0
total ind. combustion	918	622	398	476	523	578
ind. process	110	110	110	110	110	110
total industry	1028	732	508	586	633	688
traffic						
6. private cars petrol	8	8	9	10	10	10
14.private cars diesel	8	9	9	10	11	11
7. other road transport	34	37	39	45	47	49
total road transport	50	54	57	65	68	70
8. railway traffic	7	5	5	6	6	7
9. water traffic interior	25	27	29	32	34	36
10.air traffic	1	1	1	1	1	1
total traffic	83	87	92	104	109	114
non-industrial-combustion						
11.agriculture	19	18	15	17	19	21
12.services and gov.	77	86	67	76	83	93
13.households	275	166	98	99	99	98
total non-industrial	371	270	180	192	201	212
15.electricity generation	1465	257	176	211	229	274
16.refineries	246	170	135	153	163	174
total overall	3194	1517	1091	1246	1335	1461

Table B.9 (cont.) EMAC results for NO_x-emissions per country per activity, 1980-2030: West Germany.

	1980	1990	2000	2010	2020	2030
industry						
1. basic industry	219	194	118	129	141	156
2. chemical ind.	54	40	25	31	34	37
3. metal prod. ind.	20	18	13	17	19	21
4. other ind.	73	67	50	52	58	64
5. construction	0	0	0	0	0	0
total ind. combustion	366	319	206	229	252	278
ind. process	20	20	20	20	20	20
total industry	396	339	226	249	272	298
traffic						
6. private cars petrol	1042	777	467	520	544	568
14.private cars diesel	19	20	21	24	25	26
7. other road transport	410	441	469	533	557	581
total road transport	1471	1238	957	1077	1126	1175
8. railway traffic	36	35	41	47	49	51
9. water traffic interior	28	30	32	36	38	40
10.air traffic	32	35	37	43	45	47
total traffic	1567	1338	1067	1203	1258	1313
non-industrial-combustion						
11.agriculture	61	58	48	55	61	67
12.services and gov.	44	49	44	50	55	61
13.households	107	80	54	55	55	55
total non-industrial	212	187	146	160	171	183
15.electricity generation	838	764	240	287	312	337
16.refineries	69	60	51	57	61	49
total overall	3071	2688	1731	1955	2072	2179

Table B.10 EMAC results for SO_2-emissions per country per activity 1980-2030: France.

	1980	1990	2000	2010	2020	2030
industry						
1. basic industry	261	202	199	239	274	313
2. chemical ind.	171	96	95	131	151	172
3. metal prod. ind.	42	22	23	33	39	44
4. other ind.	707	503	527	621	716	813
5. construction	0	0	0	0	0	0
total ind. combustion	1181	823	844	1024	1180	1342
ind. process	383	227	200	200	200	200
total industry	1564	1050	1044	1224	1380	1542
traffic						
6. private cars petrol	6	6	6	7	7	8
14.private cars diesel	10	11	11	13	14	15
7. other road transport	79	85	91	106	114	123
total road transport	95	102	108	126	135	146
8. railway traffic	7	8	9	11	12	13
9. water traffic interior	5	6	6	7	8	9
10.air traffic	1	1	1	1	1	1
total traffic	108	117	124	145	156	169
non-industrial-combustion						
11.agriculture	46	43	39	46	52	59
12.services and gov.	3	3	4	4	5	6
13.households	345	190	149	153	157	161
total non-industrial	394	236	192	203	214	226
15.electricity generation	1187	256	232	397	438	484
16.refineries	298	220	216	256	278	301
total overall	3548	1877	1810	2223	2465	2721

Table B.10 (cont.). EMAC results for NO_x-emmisions per country per activity, 1980-2030: France.

	1980	1990	2000	2010	2020	2030
industry						
1. basic industry	72	61	61	73	84	96
2. chemical ind.	46	37	37	51	58	67
3. metal prod. ind.	4	3	3	5	5	6
4. other ind.	62	50	52	62	71	81
5. construction	0	0	0	0	0	0
total ind. combustion	184	151	153	191	218	250
ind. process	43	52	30	30	30	30
total industry	227	203	183	221	248	280
traffic						
6. private cars petrol	645	550	289	330	356	386
14.private cars diesel	15	16	16	19	20	22
7. other road transport	342	368	391	455	491	531
total road transport	1002	934	696	804	867	939
8. railway traffic	29	35	41	48	52	57
9. water traffic interior	6	6	7	8	9	9
10.air traffic	27	30	33	37	42	47
total traffic	1064	1005	777	897	970	1052
non-industrial-combustion						
11.agriculture	145	136	125	146	165	187
12.services and gov.	14	16	20	24	27	31
13.households	81	57	45	46	47	49
total non-industrial	240	209	190	216	239	267
15.electricity generation	289	105	107	121	133	147
16.refineries	44	32	32	38	41	44
total overall	1865	1554	1289	1491	1631	1788

Table B.11 EMAC-results for SO_2-emissions per country per activity 1980-2030: Belgium.

	1980	1990	2000	2010	2020	2030
industry						
1. basic industry	151	109	71	98	110	103
2. chemical ind.	21	21	15	21	24	24
3. metal prod. ind.	8	7	6	9	10	11
4. other ind.	48	53	48	55	61	66
5. construction	0	0	0	0	0	0
total ind. combustion	228	190	140	183	205	204
ind. process	80	65	55	55	55	55
total industry	308	255	195	238	260	259
traffic						
6. private cars petrol	1	1	1	1	1	1
14.private cars diesel	1	1	1	1	1	1
7. other road transport	8	8	8	9	9	10
total road transport	10	10	10	11	11	12
8. railway traffic	1	1	1	1	1	1
9. water traffic interior	4	4	4	5	5	5
10.air traffic	0	0	0	0	0	0
total traffic	15	15	15	17	17	18
non-industrial-combustion						
11.agriculture	7	6	5	5	6	6
12.services and gov.	21	18	20	23	25	28
13.households	93	75	70	71	71	71
total non-industrial	121	99	95	99	102	105
15.electricity generation	294	118	182	208	222	247
16.refineries	68	47	47	50	52	53
total overall	806	532	534	612	654	682

Table B.11 (cont.). EMAC-results for NO_x-emissions per country per activity, 1980-2030: Belgium.

	1980	1990	2000	2010	2020	2030
industry						
1. basic industry	46	35	30	37	41	43
2. chemical ind.	6	5	5	6	7	8
3. metal prod. ind.	1	1	1	1	1	1
4. other ind.	7	8	8	9	10	11
5. construction	0	0	0	0	0	0
total ind. combustion	60	50	44	53	59	63
ind. process	20	20	20	20	20	20
total industry	80	70	64	73	79	83
traffic						
6. private cars petrol	129	96	58	65	68	72
14.private cars diesel	2	3	3	3	3	3
7. other road transport	93	94	94	107	112	119
total road transport	224	193	155	175	183	194
8. railway traffic	8	4	4	5	5	5
9. water traffic interior	5	5	5	5	5	6
10.air traffic	5	5	5	6	6	7
total traffic	242	207	169	191	199	212
non-industrial-combustion						
11.agriculture	7	6	5	6	6	7
12.services and gov.	8	8	9	10	11	12
13.households	22	20	18	19	19	19
total non-industrial	37	34	32	35	36	38
15.electricity generation	68	65	84	96	102	114
16.refineries	14	12	12	13	13	14
total overall	440	386	360	407	430	459

Table B.12 EMAC-results for SO_2-emissions per country per activity 1980-2030: United Kingdom.

	1980	1990	2000	2010	2020	2030
industry						
1. basic industry	344	331	374	445	489	543
2. chemical ind.	87	19	22	29	32	35
3. metal prod. ind.	136	136	146	202	225	246
4. other ind.	343	347	374	423	469	512
5. construction	5	6	8	9	10	11
total ind. combustion	915	839	924	1108	1225	1347
ind. process	0	0	0	0	0	0
total industry	915	839	924	1108	1225	1347
traffic						
6. private cars petrol	6	6	7	8	8	9
14.private cars diesel	6	6	7	8	8	9
7. other road transport	22	22	22	25	26	28
total road transport	34	34	36	41	42	46
8. railway traffic	7	7	7	8	9	9
9. water traffic interior	34	35	36	40	42	45
10.air traffic	1	1	2	2	2	2
total traffic	76	77	81	91	95	102
non-industrial-combustion						
11.agriculture	17	19	16	18	20	22
12.services and gov.	106	112	134	152	167	185
13.households	326	224	185	185	186	183
total non-industrial	449	355	335	355	373	390
15.electricity generation	2916	2376	1439	1679	1823	1958
16.refineries	284	262	278	312	331	353
total overall	4641	3910	3054	3545	3847	4150

Table B.12 (cont.) EMAC-results for NO_x-emissions per country per activity, 1980-2030: United Kingdom.

	1980	1990	2000	2010	2020	2030
industry						
1. basic industry	62	61	69	82	90	100
2. chemical ind.	31	27	30	40	44	49
3. metal prod. ind.	25	27	29	41	45	49
4. other ind.	40	44	47	53	59	64
5. construction	3	3	5	6	6	7
total ind. combustion	161	163	180	222	244	269
ind. process	100	100	100	100	100	100
total industry	261	263	280	322	344	369
traffic						
6. private cars petrol	398	297	181	202	211	223
14.private cars diesel	15	15	17	19	19	21
7. other road transport	151	155	156	177	186	197
total road transport	564	467	354	398	416	441
8. railway traffic	42	43	44	49	52	55
9. water traffic interior	38	39	40	44	47	50
10.air traffic	52	54	55	62	65	69
total traffic	696	603	493	553	580	615
non-industrial-combustion						
11.agriculture	2	3	2	2	3	3
12.services and gov.	24	25	30	34	37	41
13.households	62	53	44	44	44	43
total non-industrial	88	81	76	80	84	87
15.electricity generation	871	916	797	931	1011	1085
16.refineries	31	29	31	35	37	39
total overall	1947	1890	1675	1920	2055	2195