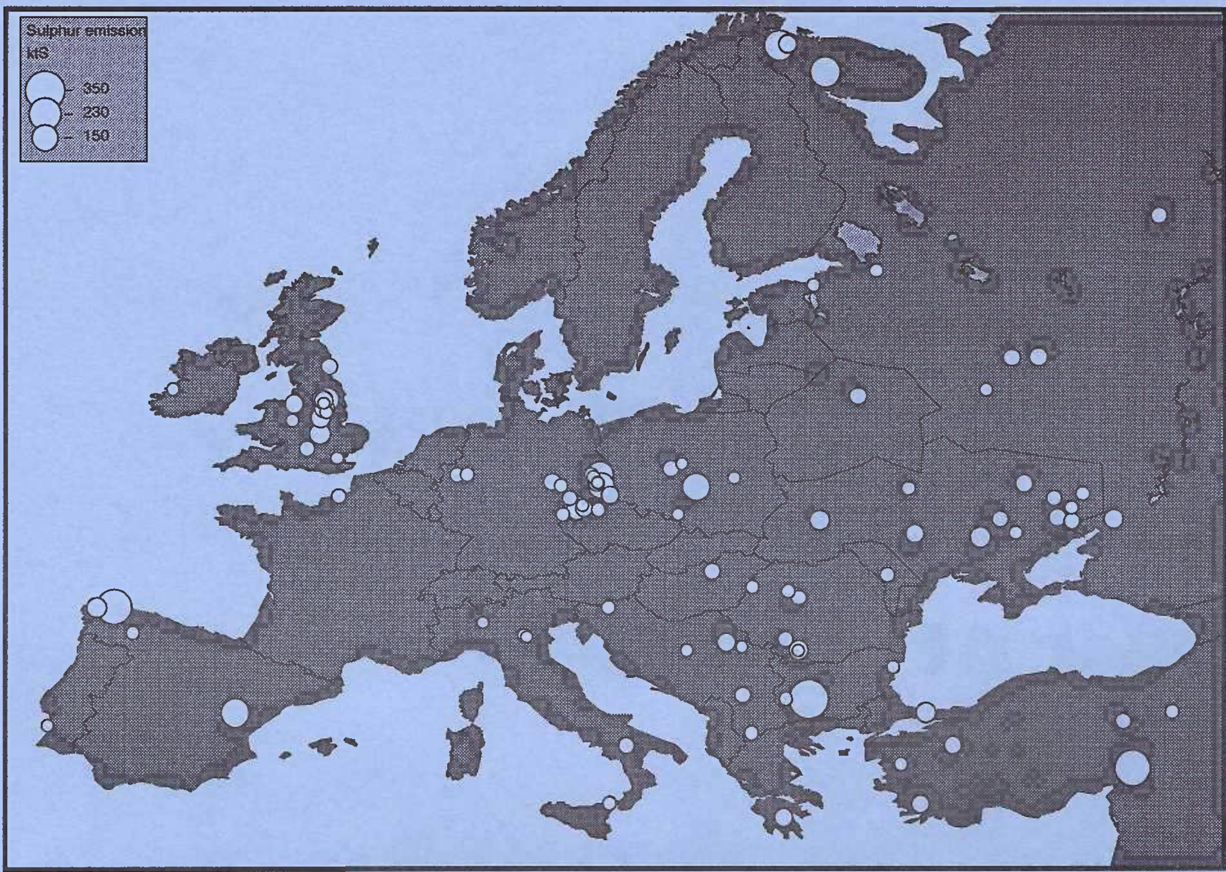
AIR POLLUTION AND CLIMATE SERIES

3

Sulphur emission from large point sources in Europe



By Mark Barrett and Rodri Protheroe

Second Edition

The Swedish
NGO Secretariat
on Acid Rain

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LARGE POINT SOURCES IN EUROPE

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Mark Barrett and Rodri Protheroe

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CONTENTS

1. SUMMARY AND RESULTS

This report describes the emission of sulphur from the largest point sources in Europe. This is the second version of a report originally published early in the summer of 1994. The significant difference between this and the first version is the use of the recently published International Energy Agency (IEA) database of coal fired power stations. This database has improved the estimation of sulphur emission from coal fired power stations. Estimates for all other sources remain the same. The first part of the report summarises the study and its results. The second part gives details of the research methodology.

The point sources are allocated to four principal categories: power stations, industries (processes such as smelters), refineries and district heating plant which do not produce electricity. The largest thousand such point sources of sulphur emission in this region contribute 80% to 90% of total anthropogenic sulphur emission for the region. These sources have tall chimneys and so are major contributors to long distance sulphur pollution. Scale economy means that it is generally cheaper to apply sulphur emission control equipment to these large plant than to smaller emission sources. For these reasons these large sulphur sources are important area for the application of policies which reduce the damage due to acid rain.

The region studied includes Europe, Scandinavia, the western states of the former USSR, and Turkey. This region contains some thirty five heterogeneous countries or federations which emit significant quantities of sulphur. Some of these have recently been, and are, in radical political and economic flux. Most of the emissions data collected and estimated relate to the period 1990 to 1992. Because of the rapid and continuing political and economic change in Europe, data for this period will often not reflect the situation in 1994. The downturn in production from heavy industries in eastern Europe and the rapid shift to low sulphur gas and imported coal in some of the more western countries is bringing about major changes in emission patterns.

The rapid political reconfiguration means that a strict comparison is not possible between every database region and ECE (Economic Commission for Europe) region. In particular, many of the point sources in the databases have not yet been reallocated from the former Yugoslavia and former USSR to their new constituent countries. Therefore data for the newer states, such as Slovenia, Croatia, Herzegovina, Bosnia, Belarus and Latvia are generally patchy; data for other countries such as Estonia and Lithuania are better because good recent data were obtained. Also, for some states, notably Russia and Turkey, much of the ECE data relates only to the western 'European' regions of these countries.

1.1 RESULTS

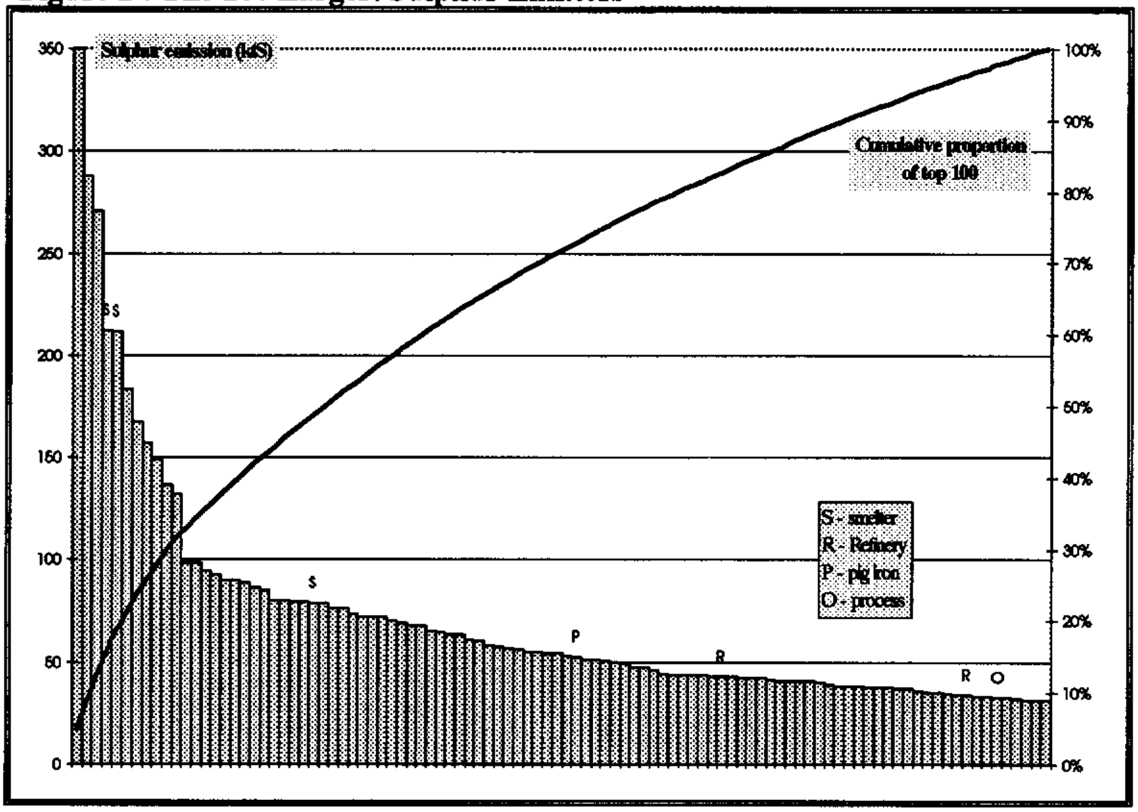
Data for the recorded or calculated sulphur emissions are in most cases given for each plant. In many cases however, more than one plant is located on the same site. For example, many electricity production sites have several power stations built over a long period. These stations may be different in design, fuels used and the application of emission control technology such as flue gas desulphurisation (FGD). Power stations, particularly those providing district heating, may be clustered around cities. Separate refineries are often located close to each other in a complex. The emission data in tables and maps are mostly aggregated by site to give point sources which in many cases comprise more than one plant. For Italy, data provided by IIASA (the International Institute for Applied Systems Analysis) have been extensively used but the proper names of the plant are not given with the data. If it is not clear which plant the IIASA data refers to, the IIASA name consisting of a plant type and number is given.

Table 1 show the largest 100 sulphur emitters in the region. The type of plant is given along with the emission estimate for a given year. Where data for actual emissions is available this is indicated. Sources of the same type are aggregated by site (usually town name). An appendix gives the addresses of the utilities named in the Table.

Of the largest 100 sources, 93 are power stations. The three biggest sources, Maritsa (Bulgaria), Afsin-Elbistan (Turkey) and Puentes Garcia Rodriguez (Spain), are power stations and they make up 13% of total emission from the top 100. Three smelters appear in the list with those in the Kola Peninsula being the largest. Two refineries, one pig iron plant and one industrial process plant appear in the largest 100, but no district heating plant.

Figure 1 shows the size distribution of the 100 largest sources. It illustrates the dominance of power stations and the importance of the very largest sources.

Figure 1 : The 100 Largest Sulphur Emitters



The importance of good information about parameters such as fuel sulphur content is underlined by comparing the estimated emission of 168 ktS (thousand tonnes of sulphur emitted) from the 4320 MW (Mega Watts - one million Watts) power station aggregate at Belchatow in Poland with that of 271 ktS from the 1400 MW Spanish plant Puentes Garcia Rodriguez. Puentes Garcia Rodriguez emitted nearly five times as much sulphur per MW of installed electrical capacity. Even then, the situation is changing rapidly. Some Spanish plant originally burnt only lignite with a sulphur content of 3330 t/PJ (tonnes per Peta Joule; 1 PJ = 10^{15} Joules of fuel energy), one of the most sulphurous fuels in the whole region. Some of this is being replaced with imported coal with a sulphur content nearer to 500 t/PJ which is less than a sixth of the sulphur per energy in the fuel. This change will substantially reduce emission.

Table 1 also gives estimates of carbon dioxide emission for most power stations expressed in Mt of carbon. Carbon emission estimates for other plant types have not been estimated. In total the power stations in the top 100 are estimated to emit 198 MtC (million tonnes of carbon) of carbon (dioxide). Carbon emission is estimated using standard International Energy Agency (IEA) coefficients as applied to fuel burn estimates for power stations.

Table 1 : The Largest Sulphur Emitters

	Site name		Cap MWe	Utility		Sul ktS	Sulphur reference	Car MtC
1	Maritsa East	PS	2060	NEK	BUL	350	1989/90 (World Bank)	5
2	Afsin-Elbistan	PS	1376	TEK	TUR	288		2
3	Puentes (As Pontes)	PS	1400	ENDESA	ESP	271	1992 (AEDENAT)	3
4	Montsegorsk	Sm			RUS	212	c 1990 (Sulphur)	-
5	Nikel	Sm			RUS	211	c 1990 (Sulphur)	-
6	Teruel	PS	1050	ENDESA	ESP	183	1992 (AEDENAT)	2
7	Belchatow	PS	4320	Elektrownia Belchatow	POL	168		8
8	Janschwalde	PS	3000	VEAG	DEU	157	1993 (Umwelt Bundes Amt)	5
9	Boxberg	PS	3520	VEAG	DEU	149	1993 (Umwelt Bundes Amt)	5
10	Prunerov	PS	1490	CEZ	RCZ	137	IIASA	2
11	Drax	PS	3960	PG	GBR	132	1992 (Dept. Env)	7
12	Cottam	PS	2018	PG	GBR	98	1992 (Dept. Env)	3
13	Tusimice	PS	1130	EZ	RCZ	98	IIASA,	1
14	Krivorozhskaya	PS	3000	Dnepenergo (MPI)	UKR	95		5
15	Burshtynskaya	PS	2400	Lvovenergo (MPI)	UKR	92		4
16	Ratcliffe-On-Soar	PS	2008	PG	GBR	90	1992 (Dept. Env)	3
17	Meirama	PS	550	FENOSA	ESP	90	1992 (AEDENAT)	1
18	Yenikoy (Yentes)	PS	420	TEK	TUR	89		1
19	Ferrybridge	PS	2000	PowerGen plc	GBR	86	1992 (Dept. Env)	3
20	West Burton	PS	2000	National Power plc	GBR	85	1992 (Dept. Env)	3
21	Fiddler's Ferry	PS	2000	PowerGen plc	GBR	80	1992 (Dept. Env)	3
22	Novocherkasskaya	PS	2400	Rostovenergo	RUS	80		3
23	Lodyzhinskaya	PS	1800	Vinnitsenergo (MPI)	UKR	80		3
24	Isalnita	PS	985	RENEL	ROM	79		1
25	Zapoljarnyj	Sm			RUS	79		-
26	Nikola Tesla	PS	2890	ES	YUG	78		4
27	Ryazanskaya	PS	1200	Ryazanenergo	RUS	76		2
28	Megalopolis	PS	300	PPC	GRE	76	1991 (Utility comm.)75.94	0
29	Eggborough	PS	1800	National Power plc	GBR	73	1992 (Dept. Env)	3
30	Irini	PS	550	PPC	GRE	72		1
31	Turow	PS	2000	Elektrownia Turow	POL	72		4
32	Seyitomer (Somtes)	PS	600	TEK	TUR	72		1
33	Zmiyevskaya	PS	2400	Kharkovenergo (MPI)	UKR	70		4
34	Kurakhovskaya	PS	1470	Donbassenergo (MPI)	UKR	69		3
35	Yatagan (Yates)	PS	630	TEK	TUR	68		1
36	Lukomyl	PS	2400		RUS	68		3
37	Thierbach	PS	840	VEAG	DEU	65	1993 (Umwelt Bundes Amt)	1
38	Kashiri	PS	2070		RUS	64		2
39	Pocerady	PS	1200	CEZ	RCZ	63	IIASA	2
40	Lippendorf (Bohlen)	PS	600	VEAG	DEU	63	1993 (Umwelt Bundes Amt)	1
41	Matra	PS	800		HUN	60		1
42	Blyth	PS	660	National Power plc	GBR	60	1990 (Green Peace)	1
43	Starobeshevo	PS	2000	Donbassenergo (MPI)	UKR	58		3
44	Pridneprovskaya	PS	1800	Dnepenergo (MPI)	UKR	57		3
45	Brindisi Sud	PS	2640	ENEL	ITA	57		3
46	Kangal	PS	300	TEK	TUR	56		1
47	Zuevskaya	PS	1200	Donbassenergo (MPI)	UKR	55		2
48	Adamow	PS	600	Zespol Elektrowni PAK	POL	55		1
49	Kosovo	PS	2618	ES	YUG	54		4
50	Hagenwerder	PS	1200	VEAG	DEU	54	1993 (Umwelt Bundes Amt)	2

Table 1 (cont.) : The Largest Sulphur Emitters

	Site name		Cap MWe	Utility		Sul ktS	Sulphur reference	Car MtC
51	Cherepetskaya	PS	1500	Tulaenergo	RUS	53		2
52	Kremikovtsi	PI			BUL	53	1989-90 (World Bank)	-
53	Didcot	PS	2000	National Power plc	GBR	51	1992 (Dept. Env)	2
54	Chemnitz	PS	255	ESAG	DEU	51		0
55	Ludus	PS	800		ROM	51		1
56	Porcheville	PS	2340	EdF	FRA	50		2
57	Slavyanskaya	PS	2100	Donbassenergo (MPI)	UKR	49		3
58	Moldavia	PS	2520		MOL	47		3
59	Fortuna	PS	801		DEU	47		1
60	Bitola	PS	630	ESM	MAC	46		1
61	Luganskaya	PS	1600	Donbassenergo (MPI)	UKR	44		2
62	Melnik	PS	1276	CEZ	RCZ	44		2
63	Turceni	PS	2310	RENEL	ROM	43		1
64	Mintia	PS	1260	RENEL	ROM	43		1
65	Soma	PS	990	TEK	TUR	43		1
66	Tisova	PS	322	CEZ	RCZ	43	IIASA	0
67	Milazzo	Ref			ITA	43	c 1990(IIASA)	-
68	Bobovdol	PS	630	NEK	BUL	43	1989/90 (World Bank)	1
69	Uglegorskaya	PS	1200	Donbassenergo (MPI)	UKR	42		2
70	Sostanj	PS	1389	ELES,	SLV	42	1990? (IIASA),	2
71	Compostilla	PS	1312	ENDESA	ESP	42	1992 (AEDENAT)	2
72	Tripolskaya	PS	1200	Kiyevenergo (MPI)	UKR	41		2
73	Gerstein	PS	1698	VEW	DEU	41		2
74	Lubbenau	PS	900	VEAG	DEU	41	1993 (Umwelt Bundes Amt)	1
75	Belovskaya	PS	1200	Kuzbassenergo	RUS	41		2
76	Zaporozhye	PS	1200	Dnepenergo (MPI)	UKR	41		2
77	Kirishi	PS	2070		RUS	40		1
78	High Marnham	PS	1000	PowerGen plc	GBR	39		1
79	Espenhaim	PS	310	MIBRAG	DEU	39		1
80	Rosanno	PS	1280		ITA	38		2
81	Oradea	PS	380	RENEL	ROM	38		1
82	Vetschau	PS	1200	VEAG	DEU	38	1993 (Umwelt Bundes Amt)	1
83	Varna	PS	1260	NEK	BUL	38	1989/90 (World Bank)	2
84	Balti	PS	1435		EST	37	(Utility comm.)	2
85	Ironbridge	PS	988	National Power plc	GBR	37	1992 (Dept. Env)	2
86	Tuzla	PS	779	EPBiH	YUG	37		1
87	Sines	PS	1256	EDP	POR	36		2
88	Rovinari	PS	1720	RENEL	ROM	35		1
89	Schwarze Pumpe	PS	1275	ESPAG	DEU	35	1993 (Umwelt Bundes Amt)	1
90	Moneypoint	PS	915	ESB	IRE	34		1
91	Kingsnorth	PS	2000	PowerGen plc	GBR	34	1992 (Dept. Env)	3
92	MZRP Plock	Ref			POL	34	1990 (IIASA)	-
93	Drmno	PS	700	ES	YUG	33		1
94	Kozienice	PS	2600	ZEK	POL	33		2
95	Chemopetrol	Pro			RCZ	33		-
96	Rybnik	PS	1600	Elektrownia Rybnik	POL	33		2
97	Ostiglia	PS	1220		ITA	32		1
98	La Casella	PS	1200		ITA	32		1
99	Sermide	PS	1200		ITA	32		1
100	Thorpe Marsh	PS	1000	National Power plc	GBR	31	1992 (Dept. Env)	1

Table 2 lists the top 100 sources by all countries.

Table 2 : The Largest Sulphur Emitters By Country

Country	Site name	Class	Rank	Sulphur (ktS)	Carbon (MtC)
Belarus	Lukomyl	PS	36	68	3
Bulgaria	Maritsa East	PS	1	350	5
	Kremikovtsi	Pig Iron	52	53	-
	Bobovdol	PS	68	43	1
	Varna	PS	83	38	2
Czech Rep.	Prunerov	PS	10	137	2
	Tusimice	PS	13	98	1
	Pocerady	PS	39	63	2
	Melnik	PS	62	44	2
	Tisova	PS	66	43	0
	Chemopetrol	Process	95	33	-
Estonia	Balti	PS	84	37	2
France	Porcheville	PS	56	50	2
Germany	Janschwalde	PS	8	157	5
	Boxberg	PS	9	149	5
	Thierbach	PS	37	65	1
	Lippendorf (Bohlen)	PS	40	63	1
	Hagenwerder	PS	50	54	2
	Chemnitz	PS	54	51	0
	Fortuna	PS	59	47	1
	Gerstein	PS	73	41	2
	Lubbenau	PS	74	41	1
	Espenhaim	PS	79	39	1
	Vetschau	PS	82	38	1
	Schwarze Pumpe	PS	89	35	1
Great Britain	Drax	PS	11	132	7
	Cottam	PS	12	98	3
	Ratcliffe-On-Soar	PS	16	90	3
	Ferrybridge	PS	19	86	3
	West Burton	PS	20	85	3
	Fiddler's Ferry	PS	21	80	3
	Eggborough	PS	29	73	3
	Blyth	PS	42	60	1
	Didcot	PS	53	51	2
	High Marnham	PS	78	39	1
	Ironbridge	PS	85	37	2
	Kingsnorth	PS	91	34	3
	Thorpe Marsh	PS	100	31	1
Greece	Megalopolis	PS	28	76	0
	Irini	PS	30	72	1
Hungary	Matra	PS	41	60	1
Ireland	Moneypoint	PS	90	34	1
Italy	Brindisi Sud	PS	45	57	3
	Milazzo	Refinery	67	43	-
	Rosanno	PS	80	38	2
	Ostiglia	PS	97	32	1
	La Casella	PS	98	32	1
	Sermide	PS	99	32	1
Macedonia	Bitola	PS	60	46	1
Moldavia	Moldavia	PS	58	47	3

Table 2 (cont. 1) : The Largest Sulphur Emitters By Country

Country	Site name	Class	Rank	Sulphur ktS	Carbon MtC
Poland	Belchatow	PS	7	168	8
	Turow	PS	31	72	4
	Adamow	PS	48	55	1
	MZRP Plock	Refinery	92	34	-
	Kozienice	PS	94	33	2
	Rybnik	PS	96	33	2
Portugal	Sines	PS	87	36	2
Romania	Isalnita	PS	24	79	1
	Ludus	PS	55	51	1
	Turceni	PS	63	43	1
	Mintia	PS	64	43	1
	Oradea	PS	81	38	1
	Rovinari	PS	88	35	1
Russian Fed.	Montsegorsk	Smelter	4	212	-
	Nikel	Smelter	5	211	-
	Novocherkasskaya	PS	22	80	3
	Zapoljarnyj	Smelter	25	79	-
	Ryazanskaya	PS	27	76	2
	Lukomyl	PS	36	68	3
	Kashiri	PS	38	64	2
	Cherepetskaya	PS	51	53	2
	Belovskaya	PS	75	41	2
	Kirishi	PS	77	40	1
Slovenia	Sostanj	PS	70	42	2
Spain	Puentes (As Pontes)	PS	3	271	3
	Teruel	PS	6	183	2
	Meirama	PS	17	90	1
	Compostilla	PS	71	42	2
Turkey	Afsin-Elbistan	PS	2	288	2
	Yenikoy (Yentes)	PS	18	89	1
	Seyitomer (Somtes)	PS	32	72	1
	Yatagan (Yates)	PS	35	68	1
	Kangal	PS	46	56	1
	Soma	PS	65	43	1

Table 2 (cont. 2) : The Largest Sulphur Emitters By Country

Country	Site name	Class	Rank	Sulphur ktS	Carbon MtC
Ukraine	Krivorozhskaya	PS	14	95	5
	Burshtynskaya	PS	15	92	4
	Lodyzhinskaya	PS	23	80	3
	Zmiyevskaya	PS	33	70	4
	Kurakhovskaya	PS	34	69	3
	Starobeshevo	PS	43	58	3
	Pridneprovskaya	PS	44	57	3
	Zuevskaya	PS	47	55	2
	Slavyanskaya	PS	57	49	3
	Luganskaya	PS	61	44	2
	Uglegorskaya	PS	69	42	2
	Tripolskaya	PS	72	41	2
	Zaporozhye	PS	76	41	2
Yugoslavia	Tuzla	PS	86	37	1
	Nikola Tesla	PS	26	78	4
	Kosovo	PS	49	54	4
	Drmno	PS	93	33	1

Table 3 summarises emission data for the regions, and for all the point sources of sulphur in the geographical region recorded in the database (1289 point sources), for the largest 100 point sources of sulphur.

ECE data for total sulphur emissions from the ECE countries are given in kt of sulphur for various years. For countries marked * ECE data refer to emissions from the region covered by the EMEP grid only. Some of these emissions are estimates. Total country emissions are also expressed as a percentage of total emission from the ECE region (excluding emissions from marine transport and natural sulphur emission). Country emissions do not sum to 100% of ECE because of the omission of small emitters such as Liechtenstein and Iceland. The ECE data used did not include Moldavia.

Total emissions from all sources in the database and the largest 100 point sources are given in ktS, and as a percentage of each country's total emission. In some instances the sum of all sources in the database is more than the country total reported to the ECE. This may be for one or more reasons: change of political boundaries; the inclusion of point sources outside the EMEP region; the point source and country data are for different years; the data may be wrong either as reported to the ECE, or as used and assumed by *Pollen*. In general such inconsistencies in the data for the largest 100 sources are smaller and fewer because information about the large sources is better.

Some separate data are given for emission from electric power stations. The largest 100 sources make up some 42% of total sulphur emission for the ECE region.

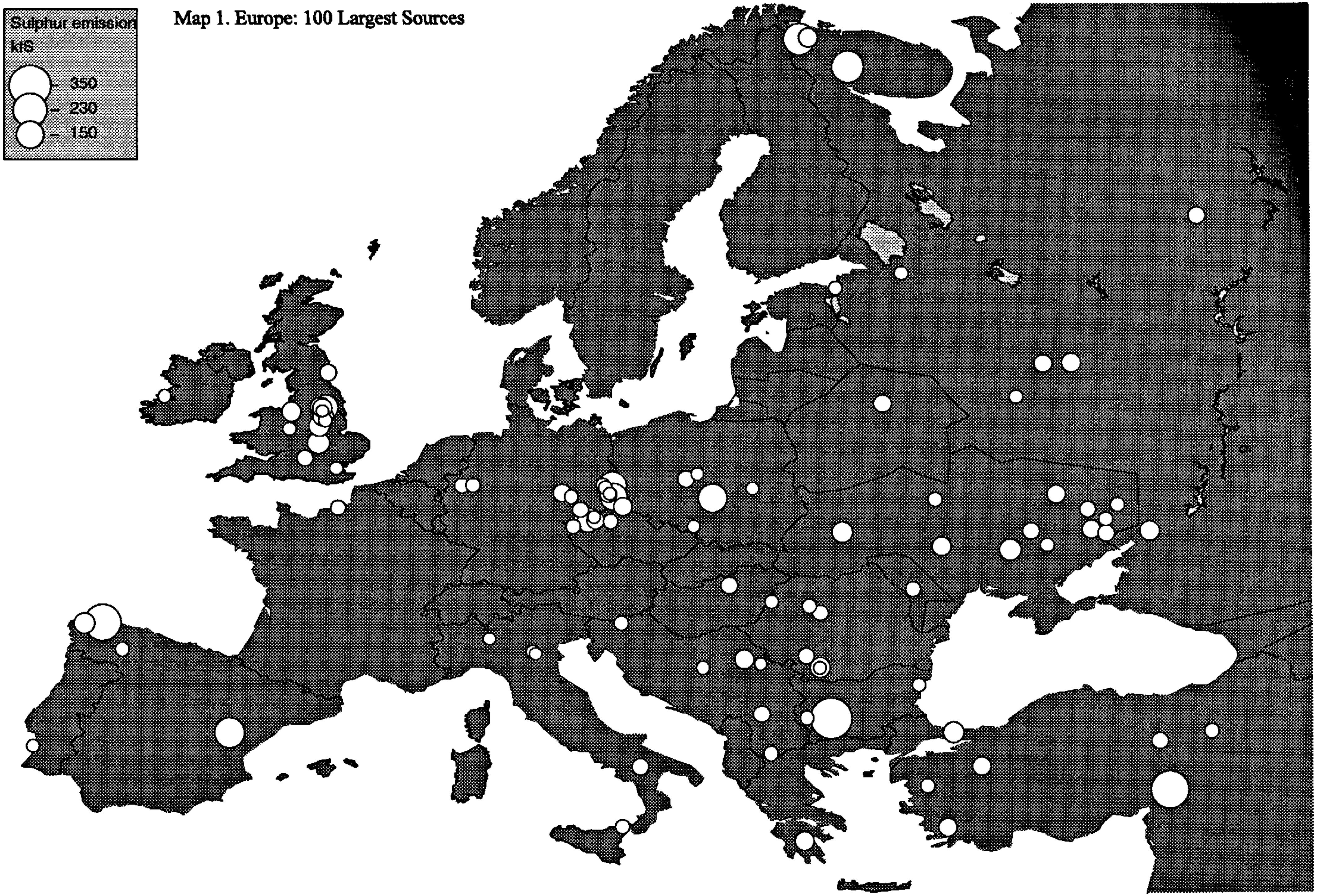
Table 3 : Summary of Sulphur Emission

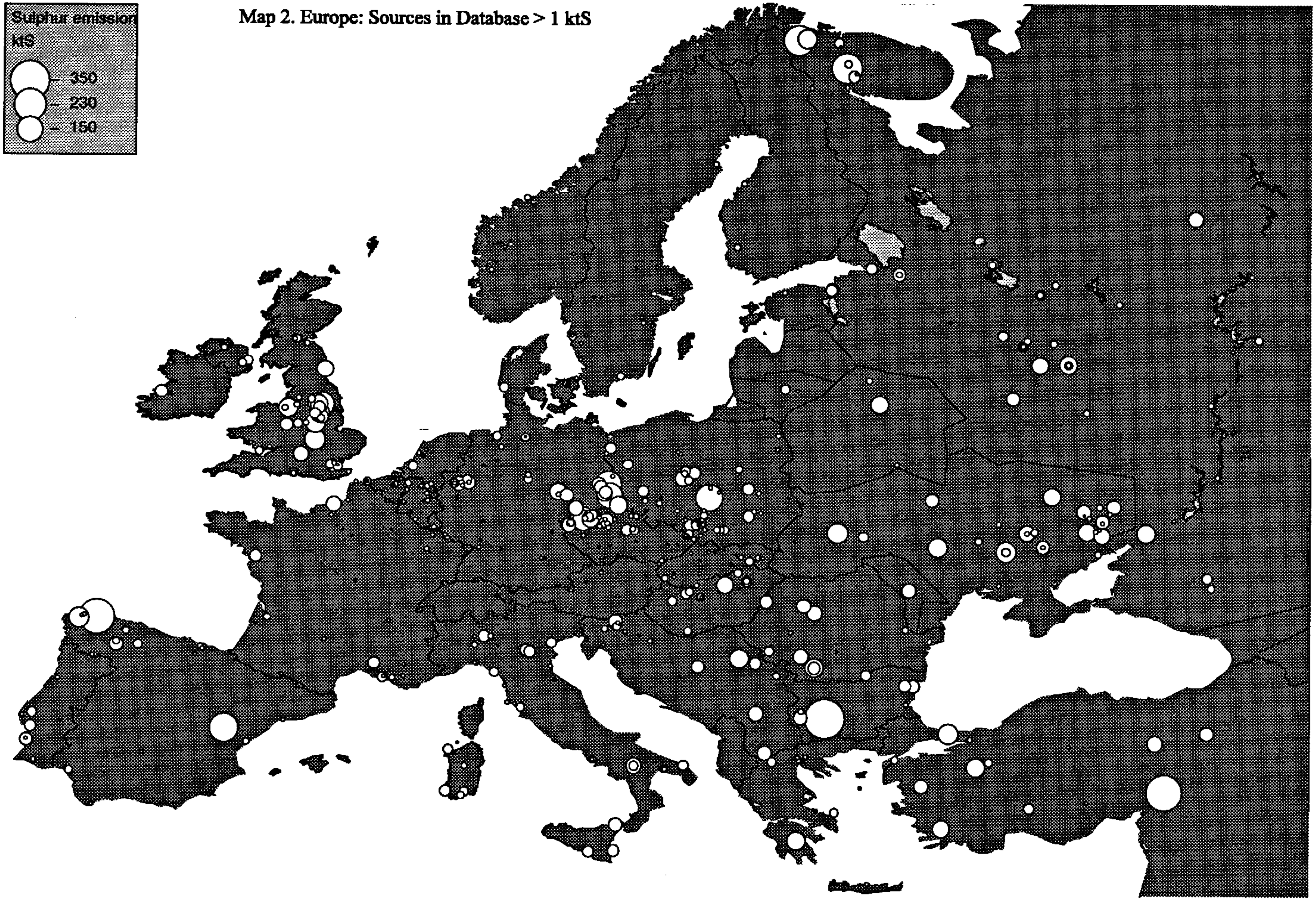
	Total emission ECE reported		All sources in Db All classes		Elec	Top 100 All classes		Elec	
	ktS	% ECE	ktS	%cntry	%cntry	ktS	%cntry	ktS	%cntry
Albania	60	0.4%	3	4%	0%				
Austria	38	0.2%	23	59%	24%				
Belgium	156	0.9%	89	57%	26%				
Belarus	298	1.8%	68	23%	23%	68	23%	68	23%
Bulgaria	560	3.3%	562	100%	90%	483	86%	430	77%
Switzerland	30	0.2%	7	22%	13%				
Germany	2275	13.5%	1711	75%	67%	780	34%	780	34%
Denmark	122	0.7%	103	85%	83%				
Spain	1158	6.8%	984	85%	80%	586	51%	586	51%
Estonia	90	0.5%	70	78%	78%	37	42%	37	42%
Finland	97	0.6%	119	123%	86%				
France	604	3.6%	497	82%	67%	50	8%	50	8%
Great Britain	1783	10.5%	1345	75%	73%	898	50%	898	50%
Greece	255	1.5%	223	88%	83%	148	58%	148	58%
Hungary	451	2.7%	198	44%	42%	60	13%	60	13%
Ireland	80	0.5%	56	71%	70%	34	43%	34	43%
Italy	1090	6.4%	864	79%	52%	233	21%	190	17%
Lithuania	68	0.4%	21	31%	31%				
Luxembourg	8	0.0%	6	69%	0%				
Macedonia	5	0.0%	55	1091%	1091%	46	916%	46	916%
Moldavia	46	0.3%	47	104%	104%	47	104%	47	104%
Netherlands	89	0.5%	116	131%	90%				
Norway	20	0.1%	27	135%	12%				
Poland	1410	8.3%	813	58%	48%	394	28%	360	26%
Portugal	142	0.8%	108	76%	70%	36	25%	36	25%
Czech Rep.	769	4.5%	526	68%	68%	385	50%	385	50%
Romania	752	4.4%	508	68%	64%	290	39%	290	39%
Slovak Rep.	187	1.1%	281	150%	26%	33	18%	0	0%
Russian Fed.*	2200	13.0%	1911	87%	48%	857	39%	355	16%
Slovenia	94	0.6%	67	71%	71%	42	45%	42	45%
Sweden	51	0.3%	134	262%	213%				
Turkey *	177	1.0%	781	441%	431%	616	348%	616	348%
Ukraine	1188	7.0%	818	69%	69%	794	67%	794	67%
Yugoslavia	335	2.0%	347	104%	95%	202	60%	202	60%
Total	16686		13488			7119		6455	
%ECE	99%		80%			42%		38%	

1.1.1 Maps

A mapping package developed by *Pollen* was used to produce maps of the point sources. The region to be mapped is large, and plant are often clustered in regions. This means that many of the symbols and names of the sources mapped overlap. (This problem could be remedied by aggregating all sources within a certain distance of each other.) Map 1 shows the top 100 sources. Map 2 shows all the sources in the database of over 1000 sources for which spatial coordinates have been recorded and for which emission is greater than 1 ktS. Note that recording spatial coordinates is very time consuming and so many large sources are not shown on this map. Map 3 shows those amongst the top 100 sources lying in the central European area around the intersection of Germany, Poland and the Czech Republic. Map 4 shows the largest sources in Britain.

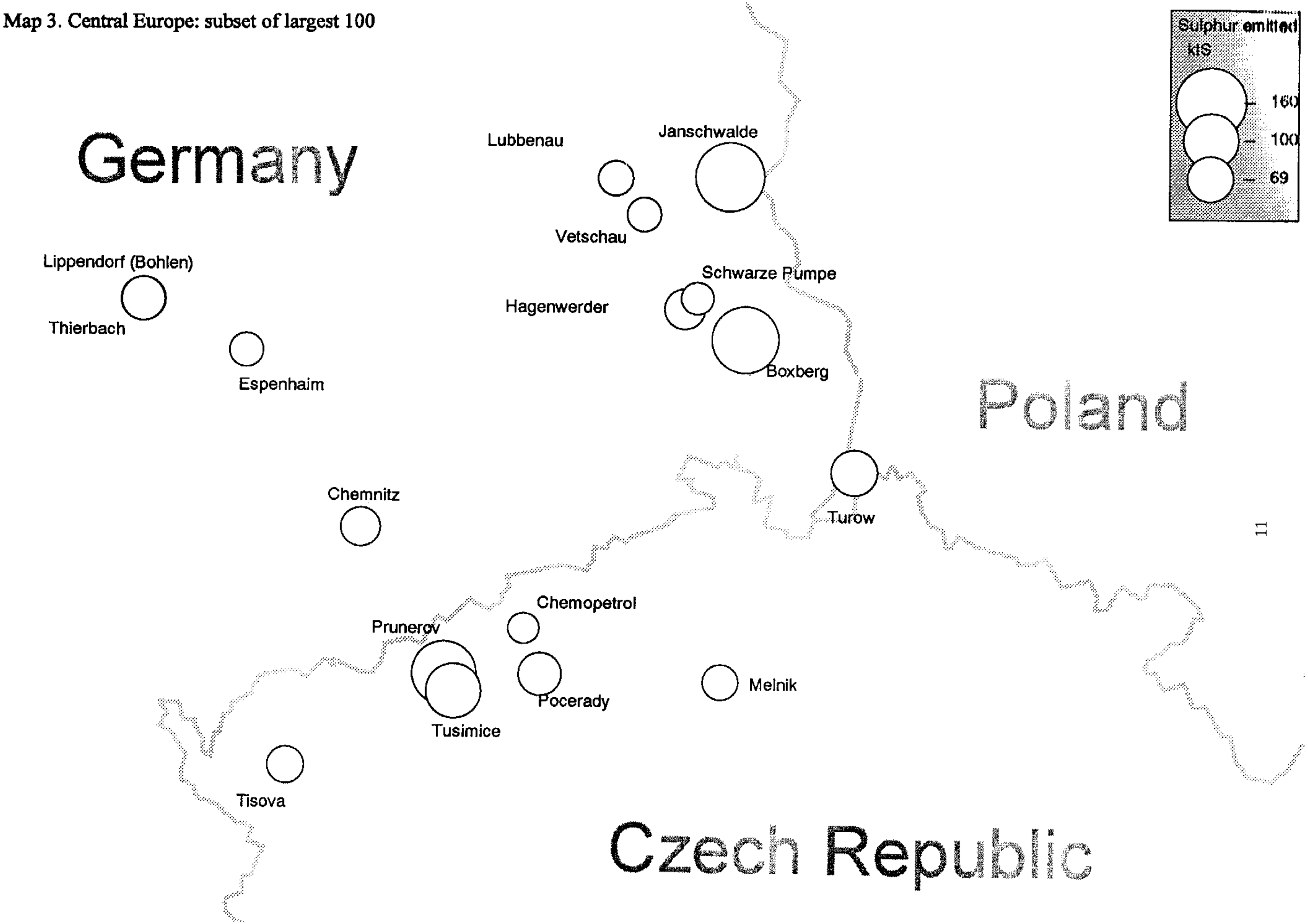
Map 1. Europe: 100 Largest Sources



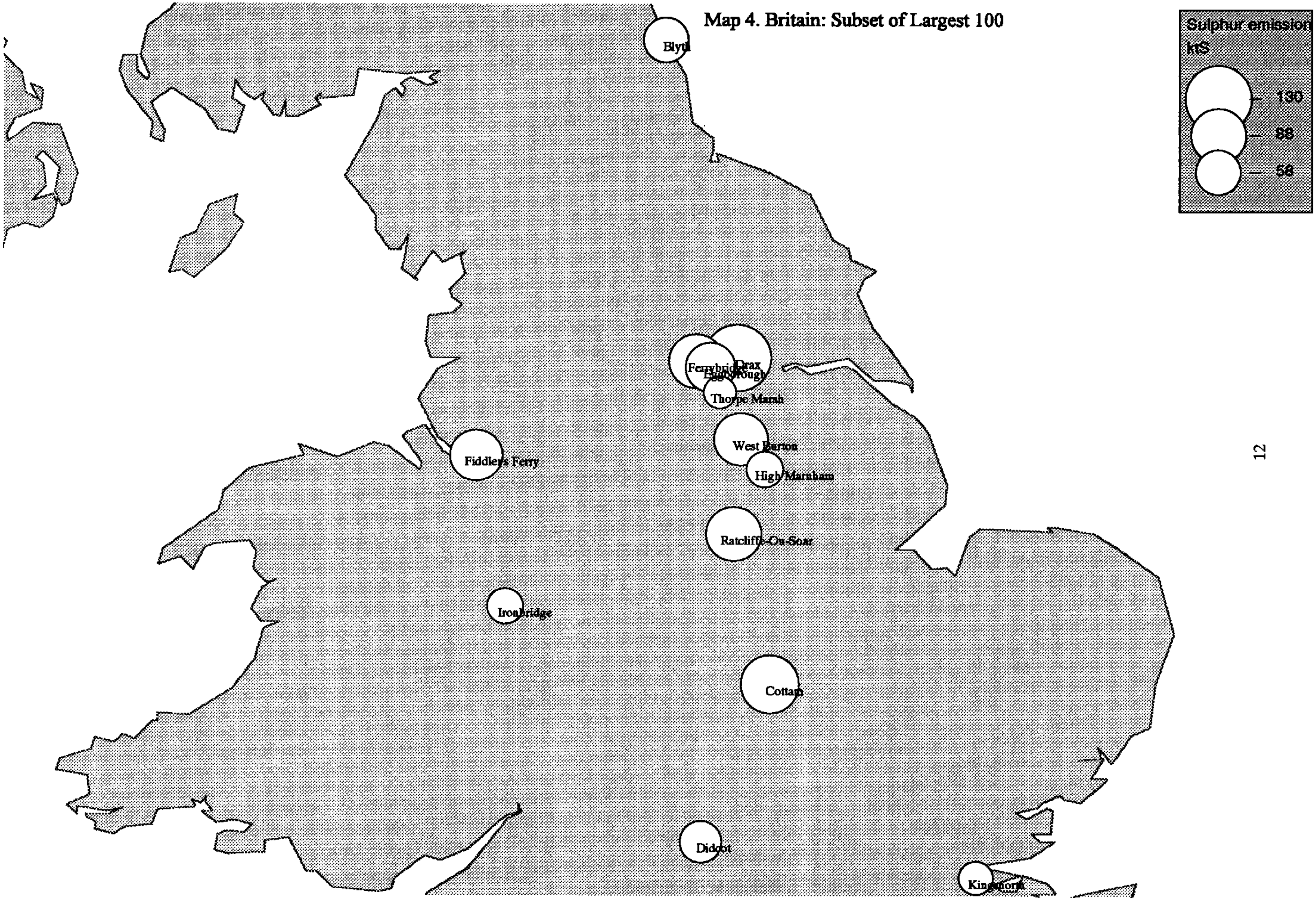


Map 2. Europe: Sources in Database > 1 ktS

Map 3. Central Europe: subset of largest 100



Map 4. Britain: Subset of Largest 100



1.1.2 Emission control costs

It is not a prime aim of this work to investigate the costs of controlling sulphur emission from these sources. To do so properly would require an investigation of the all the available methods including energy efficiency, conservation, fuel switching, renewables and 'end-of-pipe- technologies. It is nonetheless interesting to estimate the cost of reducing sulphur emission with flue gas desulphurisation (FGD). This cost estimate should provide an upper limit to the actual cost of emission control.

The International Energy Agency (Flue Gas Desulphurisation Performance Experience, 1993) has recently analysed the costs and performance of FGD. For the common wet scrubbers designs capital costs typically range around $220 per kW of electrical output of a power station. The total levelised cost of sulphur removal is about $600 per tonne. These costs vary widely depending on the many factors including station size, site characteristics and fuel costs. Wet FGD systems decrease the efficiency of power stations by 1 to 2 percentage points and thereby increase carbon dioxide emission by between 2% and 8%.

The largest 100 sources include power stations with an aggregate electrical capacity of 138 GWe. Fitting FGD to these stations would cost about $30 billion in capital cost. This would reduce sulphur emission by about 6200 kt in the region concerned. This is about 38% of the ECE total. The total levelised annual cost would be some $4.3 billion per annum.

It is emphasised that FGD is not generally the best emission control option for the first tranche of emission reduction. As compared to energy efficiency it is expensive and has its own environmental impacts such as limestone mining and waste dumping.

2. RESEARCH METHODOLOGY

The work carried out was divided into four phases:

i. Collection of basic data

ii. Collation and estimation of emission

iii. Aggregation of point sources

iv. Reporting including the presentation of tables and maps of largest emitters

The biggest problem has been finding the location of these sources and data enabling estimates of sulphur emission to be made. The great majority of large sources is coal fired power stations. A few smelters are very large emitters, and some refineries are sizeable too.

2.1 DATA SOURCES

The authors could find no comprehensive database covering all the types of emitter for the region concerned, and so many disparate sources of data were utilised. Reconciling these different sources has caused great problems. For example; the sources will give inconsistent information about a particular emitter; sometimes it is not clear which emitter the data refers to and there is the problem of potential double counting. The rapidly changing political boundaries and affiliations coupled with the large number of languages of the region has added to the difficulties.

Basic data coverage for the Russian Federation and eastern Europe is poor in detail and in having recent data. Unfortunately many of the largest sources are in this region. Furthermore, these regions have manifested great changes in economic output because of political change. Thus, even where good data exists for some past year, it may bear little relation to the current position.

The principal sources used were:

i. Standard letters were sent to 130 Government Energy and Utility authorities, 400 electricity utilities, and 70 Government and non-government environment groups. These mail shots covered all of the countries of the region in question. The letters requested specific data about point sources, and more general information about total emissions, emissions control policies and so on (see Appendix for letter to electricity utilities). The response rate was generally poor with some 10% of the letters sent answered with useful information. Many replies to the circular letters gave confidentiality or cost as reasons for not supplying data. Despite this, data provided for a few countries are very good indeed. Little of the data refers to years later than 1990-1991.

ii. The International Institute for Applied Systems Analysis (IIASA) provided us with an emissions database. This database gives data for 187 regions of the Central European Initiative covering Austria, Croatia, the Czech Republic, Hungary, Italy, Poland, the Slovak Republic and Slovenia. The database has information on 402 large point sources of emission including industrial sources in this area. The IIASA data is recent and gives most of the required details except, for some plant, the name. This is for reasons of confidentiality. The problem then is to ensure no double counting occurs.

iii. Previous data collated by Barrett in 1988 served as the foundation for the power station database. The IEA has produced a database of coal fired power and this has been used extensively.

iv. The International Energy Agency (IEA) databases of energy balances and energy flows for 1989 were used in emission calculation for refineries and power stations.

v. Other important sources were the UK Department of Environment (DoE) and the Stockholm Environment Institute at York (SEIY).

Table 4 lists general and specific country coverage of the principal data sources.

Table 4 : Principal Data Sources and Coverage

Countries	General	Power stations	Industry	District heating	Refineries
ALL	Circular letter, World Bank, IEA	Barrett, IEA	SEIY		Pennwell
Austria AUT	IIASA				
Croatia CRO	IIASA				
Czech Republic RCZ	IIASA				
Great Britain GBR	DoE				
Hungary HUN	IIASA				
Italy ITA	IIASA				
Poland POL	IIASA			IEA	
Slovak Republic RSL	IIASA				
Slovenia SLV	IIASA				

Note: Pennwell Oil Refining Directory (1992)

2.1.1.1 Pertinent data sources not used

There are some databases which would supplement the data collected but have not been used because of expense or confidentiality.

i. European Union (EU) countries report the sulphur and NOx emissions from large combustion plant to the European Commission (EC) under the Large Combustion Plant Directive (LCPD).

These data are generally confidential, but the UK have published them.

ii. The CORINAIR programme collects emissions data for EU countries. The company who manages this data, CITEPA, were approached but the cost of supplying the data was too high for this project. Some of the data may in any case be insufficient and out of date.

2.1.2 Classification of point source

Point sources have been allocated to one of four categories: power stations, industries, refineries and district heating. For each point source data are required on plant name, emission and spatial location. These are discussed in turn below.

2.1.3 Plant name

The name of the plant is generally the key to identification. In most cases the name is that of a nearby city or town, or some other geographical feature. This has enabled the longitude and latitude to be at least approximately found.

2.1.4 Estimated sulphur emission for year

There are limited data detailing the actual historical emissions from individual sources. However these data are very patchy, often old, and do not necessarily refer to the same year.

Calculations have therefore been extensively used to estimate emissions. It has not been possible to use sophisticated modelling techniques given the resources allocated to this study. Calculations have been relatively simple and use many assumptions based on judgement rather than hard data. The emission of the point sources depends on three basic factors: plant output, the sulphur contents of inputs, and the application of sulphur removal equipment. The emission of a source can vary widely from year to year if one or more of these factors change :

i. **Varying production.** For whatever reason the production from any particular source vary between zero and maximum capacity from one year to the next. The plant might be closed down or out of operation for some other reason such as maintenance. Alternatively plant not used one year might be required the next because other plant are not available: for example, drought and nuclear power problems in France decreased hydro and nuclear output, and fossil power stations had to be used more extensively.

ii. **Fuel or input change.** The sulphur content of the fuel or feedstock for the plant might change. For example, if a UK power station switches from UK coal to imported coal (with typically about half the sulphur content of UK coal), sulphur emission will be halved.

iii. **Sulphur removal.** Some sulphur may be retained by the ash of the fuel burnt: this might be in the range 5% to 30% for coal fired power stations. Sulphur can additionally be removed before, during or after combustion by a number of processes which produce waste for dumping, or products for sale such as gypsum, elemental sulphur or sulphuric acid. Typically these processes reduce sulphur emission by 60-90%.

Because of uncertainties in these factors the estimates of sulphur emission made by the authors as described below may be quite inaccurate for a certain plant in a particular year: the estimated emission may be considerably greater or smaller than estimated.

2.1.5 Spatial location

The mapping programme (MAPPER) requires the longitude and latitude of each point source. The stages of estimating location were as follows:

i. For some point sources longitude and latitude were given in the basic data collected.

ii. For most sources, longitude and latitude were found by trying to identify the nearest city or other geographical feature indexed in a comprehensive atlas. The authors have built a database of cities which has been used to look up longitudes and latitudes. This means that for most sources the spatial error will be several kilometres. For some sources, the name is duplicated in the index or there are variants of the English spelling leading to confusion. This has doubtless led to errors.

iii. Some of the names of some sources are not related to a geographical feature, or the feature is not indexed in the atlas. In these cases the EMEP square is noted and the nearest large town is used.

2.2 POWER STATION EMISSIONS

2.2.1 Data

Previous work by Barrett in 1988 resulted in a database of some 800 individual power stations for western Europe, and 500 for eastern Europe and the western Russian Federation states. Certain key data, such as the electrical output, thermal efficiency, and sulphur contents of fuels are rarely recorded, and other important information such as the commissioning date is often missing. – Estimates of these data or default assumptions have to be made where other data (e.g. from the IEA) can not be found. This database has been updated to account for known changes over the past four years, and the spatial location (longitude and latitude) of stations recorded. Other data such as the implementation dates and removal factors for emission control have been added where known. The database now contains some 1300 fossil power stations for the region of interest. Longitude and latitude estimates have been made for the largest 200 stations.

The IEA (UK) have updated their coal fired power station. It was originally intended to use this in electronic form but the cost is too high. The database includes the east and west distance from the nearest town indexed in a standard atlas. A published subset of the has been used. The database only covers stations which can burn coal and so does not include oil or gas fired stations, or indeed nuclear or stations using renewable energy resources. The IEA have encountered problems acquiring good data for some countries, particularly for parts of the Russian Federation.

2.2.2 Emission data

Recorded data

Emission data have been supplied for the larger power stations in Great Britain, Greece, Belgium, and Estonia; and for the CEI countries covered by the IIASA data.

Estimated emission

Emissions have to be estimated for most power stations in countries other than those listed above. Emission depends on the amount and sulphur content of the fuel burnt, and the proportion of sulphur emitted to the atmosphere.

Quite good data for the sulphur contents of coal and some other fuels have been obtained from IEA publications and the circular letters. In many countries a large proportion of plant can utilise several different fuels. In such cases, it has been generally assumed that coal is used rather than oil or gas, and gas rather than oil. Coal and heavy fuel oil produce generally comparable emissions of sulphur per kWh generated and so the error in emission estimate arising from an inappropriate choice of coal or oil may not be too great: but delivered natural gas typically has negligible sulphur content and so assuming gas rather than coal or oil will introduce a very large error if gas is not actually used. The default assumed fuel burn mix has been adjusted if other pertinent information is available.

In some cases recent data for the electrical output and fuel burn of a station are also recorded. If not, it is assumed that the plant has a default efficiency (35% coal, 36% oil, 37% gas). Default load factors are also assumed (70% coal, 50% oil, 70% gas). These factors have been used to estimate fuel burn, and modified only if inconsistent with other information.

The incombustible mineral content of coal (ash) combines with sulphur during combustion to form solid residues and so reduce atmospheric sulphur emission. The proportion of sulphur so removed depends both on the nature of the ash and on combustion conditions. Figures used are 5% for hard and bituminous coals, and 25% for lignite. For oil and gas stations it is assumed that all the sulphur is emitted. The retention factor for oil shale, based on information from Estonia, is assumed to be 80%. The existence of sulphur removal equipment is quite well known for most countries. Often, however, there is not accurate information about the sulphur removal efficacy of the equipment. This typically ranges from 50% to 90%. Where data is not provided, it is assumed that 90% of the sulphur in the flue gas is removed.

Sulphur emission is then calculated:

Emission = (tonnes of fuel burn)(% sulphur in fuel)(% sulphur emitted) tS

If the fuel burn is not recorded it is calculated:

Fuel burn = (MW plant capacity)(load factor)(8760) / (Efficiency) MWh

Plainly this method of calculation is crude. However the object is to find the biggest emitters. Therefore, given reasonable fuel sulphur data, the error may not be large on average for many of the large coal fired power stations which, in most countries, are run at high load factors. Nonetheless there will be exceptions. Some large plant may only have access to expensive coal and so be utilised at less than full availability. Others may only be used extensively in exceptional circumstances because such fossil plant are generally low in the merit order (e.g. in France). The proportion of exceptional cases will be more for large plant using heavy fuel oil. These are often placed lower in the merit order than coal for reasons such as cost or fuel supply contract, and so run at low load factors.

2.3 INDUSTRIES

The principal industrial processes covered are smelting, pig iron production and wood pulping. There are very limited data providing accurate estimates of emissions from industry. What data there are however, does show very large variations for many individual plant from year to year, particularly in eastern Europe and the Russian Federation. These variations seem to be principally due to changes in output and the application of sulphur capture equipment, rather than changes in the sulphur contents of feed stock.

Emissions have been calculated for most of the sources. The general method is to apportion the national output of the product to each industrial plant according to the proportion of total national production capacity that plant represents. (An alternative approach is to assume that the largest plant are used to full capacity because they will generally be the most modern and produce at least cost, and that the smallest plant will not be used if there is national overcapacity.)

The estimated production by individual plant is then multiplied by an emission factor expressed in sulphur emitted per unit of output.

2.3.1 Smelters

There is sulphur in some ores and in the fuels used to drive smelting process. The amounts of sulphur emitted depend on the sulphur contents of these: and on the capture of sulphur dioxide either by smelting products, or by equipment which separates the sulphur for dumping or for saleable products.

2.3.1.1 Data

There are 49 smelters in the database. The principal data source was **Sulphur** (March-April 1993) listing some emissions in the Kola peninsula and supplementary data; further data came from the SEIY database of European and Eastern European Smelters (1980/1984).

2.3.1.2 Emission calculation

Metal production was apportioned to the capacities of the smelters. Emissions are calculated by multiplying production by an emission factor appropriate for that process. The factors used were:

Zinc 55 kg S per 1000 kg metal

Copper 120 kg S per 1000 kg metal

Nickel 120 kg S per 1000 kg metal

2.3.2 Pig Iron Producing Plants

The SEIY database of European and Eastern European pig iron producing plants (1980/1984) was used as a basis. Iron production was apportioned as for smelters. The emission factor used was 2.0 kg S per 1000 kg metal

2.3.3 Wood pulping operations

The SEIY database of European and Eastern European pulping operations (1980/1984) was used. Pulping operations production was apportioned by capacity as above. The emission factor used was 2.0 kg S per 1000 kg paper produced.

2.4 REFINERIES

2.4.1 Data

Most of the data for refinery capacities was taken from the Penwell directory for the year 1992. This directory does not detail Russian refineries - a supplementary database (1989) of Russian refineries was used to fill out the information.

2.4.2 Emission

The actual emissions of sulphur from refineries depends largely on the sulphur content of the crude feedstock oil and on desulphurisation that occurs during refining. These characteristics vary widely between refineries, and can change fairly quickly.

As for other sources, emissions data were taken where possible from other published estimates. The principal sources are IIASA for central Europe and the DoE for the UK.

Estimated emission

The total country use of crude oil was determined from IEA energy balance tables (1989). This figure was apportioned amongst the refineries according to their name-plate capacities. An emission factor of 0.5 kg S per 1000 kg crude oil used unless other data was available.

2.5 DISTRICT HEATING

District heating comprises plant which are used for heating only. Combined heat and power plant are included in power stations. Data is exceptionally poor because most district heating occurs in eastern Europe and the Russian Federation where data is scarce. The only good comprehensive data for large plant was found for Poland. The largest plant is about 700 MW thermal. This rating is equivalent to a power station with an electrical output of 200-300 MW. This low thermal rating for district heating plant, coupled with their low load factors as compared to most large coal power stations, means that their emissions are generally substantially less than 5 ktS. Several hundred other sources are larger than this. District heating plant have therefore been omitted from further consideration.

3. APPENDIX 1: CIRCULAR LETTER

Letter to governmental and interested national bodies

Dear Sir,

Power Station Research

We are currently researching into large stationary point sources of sulphur dioxide in Europe and the Western CIS region. For this we need information on actual emissions or data which will enable us to estimate emissions. We are anxious to provide reliable figures.

We intend to publish the study on behalf of the SWEDISH NGO SECRETARIAT ON ACID RAIN. We would therefore like the following information:

I. **A list of your country's power stations.**

Data we would like to include on each is:

- A. Station type, (coal, oil, gas etc), CHP installation, capacity (MWe)
- B. Commissioning date and decommissioning date (if known)
- C. Map location (grid reference)
- D. Desulphurisation equipment and its sulphur removal efficiency (planned and installed)
- E. Thermal efficiency (%)
- F. Electrical output (TWh)
- G. Sulphur and thermal contents of fuels burnt at present, and possible future changes

II. **Emissions**

- A. An estimate of sulphur emission from individual power stations and total sulphur emissions from all your country's power stations.
- B. Estimates of NOx emissions from your country's power stations would also be valuable.

III. **General information**

- A. Demand forecasts and capacity plans and analysis
- B. Environmental protection programmes

Any help with this information and guidance as to other sources of information would be appreciated.
Yours sincerely,

4. APPENDIX 2: UTILITY ADDRESSES

Natsionalna Elektricheska Kompania (NEK)
ul Triadiza 8
1040 Sofia
Bulgaria
- Tel1 : 359 2 885932
- Fax : 359 2 875826

Ceske Energeticke Zavody (CEZ)
Jungmannova 29
111 48 Prague 1
Czech Republic
- Tel1 : 42 2/24 22 22 49
- Tel2 : 42 2/26 89 73

Electricite de France (EdF)
2 rue Louis Murat
75384 Paris CEDEX 08
France
- Tel1 : 33 1 40 42 22 22
- Fax : 33 1 47 42 25 35

Energiewerke Schwarze Pumpe AG (ESPAG)
An der Heide
09139 Schwarze Pumpe
Germany
- Tel1 : 49 3564 36 0
- Fax : 49 3564 36 2675

Energieversorgung Sudsachen AG (ESAG)
Theaterstr. 25
09111 Chemnitz
Germany
- Tel1 : 49 371 664 2200
- Fax : 49 371 664 2277

Mitteldeutsche Energieversorgung (MIBRAG)
Thaelmannplatz 3
D-4020 Halle/Saale
Germany
- Tel1 : 49 3493 64 0
- Fax : 49 3493 64 3900

Vereinigte Energiewerke AG, Berlin (VEAG)
Allee der Kosmonauten 29
12681 Berlin
Germany
- Tel1 : 49 30 5464 2185
- Fax : 49 30 5464 2887

Public Power Corporation (PPC)
30 Chalkokondylis Street
Athens 102
Greece
- Tel1 : 30 1 523 0301
- Fax : 30 1 523 0035

Electricity Supply Board (ESB)
Lower Fitzwilliam Street
Dublin 2
Ireland
- Tel1 : 353 1 676 5831
- Fax : 353 1 676 0727

Ente Nazionale per l'Energia Elettrica (ENEL)
Via GB Martini 3
00198 Roma
Italy
- Tel1 : 39 6 85091
- Fax : 39 6 85092162

Elektrownia Belchatow (EB)
Energetikow 11
47-22 Ruda Slaska
Poland
- Tel1 : 48 44 351800
- Fax : 48 44 324202

Elektrownia Turow (ET)
Mlodych Energetykow 12
37-450 Bogatynia
Poland
- Tel1 : 34200
- Fax : 34726

Zespol Elektrowni PAK (ZEPAK)
Kazimierska 45
62-510 Konin 2
Poland
- Tel1 : 48 63 421831
- Fax : 48 63 424728

Electricidade de Portugal (EDP)
Av Jose Malhoa Lote A, 13
1000 Lisboa
Portugal
- Tel1 : 351 1 352 5353
- Fax : 351 1 339 272

Romainian Electricity Authority (RENEL)
Bd. Magheru 33
70164 Bucuresti 1
Romania
- Tel1 : 40 1 312 3163
- Fax : 40 1 312 0291

Kuzbassenergo
Stantsionnaya 17
650003 Kemerovo
Russian Federation

Mosenergo
8 Raushskaya emb
RU-113035 Moscow
Russian Federation

Rostovenergo
49 Bolshaya Sadovaya Street
RU-344007 Rostov on Don
Russian Federation
- Telx2 : 8632 38 5366

Ryazanergo
391097 Novomichurinsk
Russian Federation

Empresa Nacional de Electricidad SA
(ENDESA)
Principe de Vergara 187
ES-28002 Madrid
Spain
- Tell : 34 1 563 38 49
- Fax : 34 1 563 81 81

Union Electrica-Fenosa SA (UE-FENOSA)
Capitan Haya 53
E-28020 Madrid
Spain
- Tell : 34 1 571 3700
- Fax : 34 1 570 4349

Turkiye Elektrik Kurumu (TEK)
Ticari Isler Daire Bakanligi
Inonu Bulvari 27, Bacheliever
Ankara
Turkey
- Tell : 90 4 212 6930
- Fax : 90 4 213 8870

National Power (NP)
Windmill Hill Business Park
Whitehill Way
Swindon SN5 6PB
United Kingdom
- Tell : 0793 877777
- Fax : 0793 892 525

PowerGen (PG)
Haslucks Green Rd
Shirley
Solihull
West Midlands
B90 4PD
UK

Elektroprivreda Srbije (ES)
Carice Milice 2
11000 Beograd
Yugoslavia
- Tell : 381 11 628622
- Fax : 381 11 629489

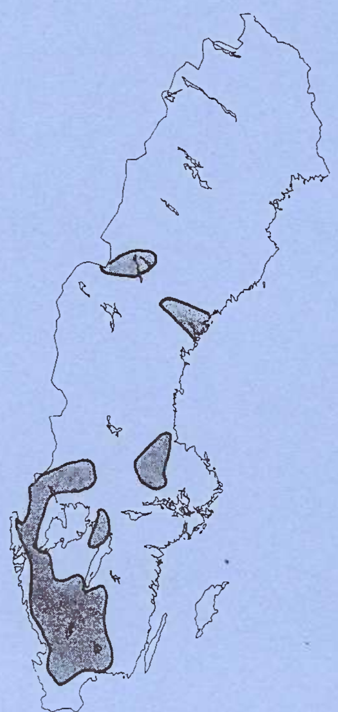
Lakes and forests in Sweden

BECAUSE OF AIR POLLUTION, close on 14,000 lakes are now distinctly acidified in Sweden – and about 4000 of them very badly so. And rapid further deterioration will ensue if acid deposition continues at the same rate as today – it being estimated that after only a few decades the number of acidified lakes will have risen to 34,000. In total, the country has something like 85,000 lakes with a surface area of more than one hectare.

Acidification has extensive biological effects in lakes. For one thing the diversity and number of aquatic species diminishes, resulting in a greatly changed ecosystem. Such effects occur already when the pH-level of the water drops below 6. Among the sensitive animal species are snails, mussels, crustaceans, and certain species of insects and fish.

As regards the effects on forest soils, the pH value of the soil on some 650,000 hectares of forest land in South Sweden is now under 4.4, which is thought to be a critical level at which release of potentially toxic metals to the soil water will start. On a further 700,000 hectares in that part of the country the pH values ranges between 4.4 and 4.7, and unless there is a dramatic reduction of the acid deposition, the acidification of these soils too will go below the critical level within a couple of decades.

One effect of acidification is the greatly increased leaching of plant nutrients from the soil. Since 1950, in some areas more than half of the available magnesium, potassium, and calcium has become lost in this way.



Areas where the forest soils are so acidified that there is a risk of extensive damage to trees and other vegetation.

National inventories of the scale and distribution of forest damage have been carried out since the mid 1980s. In 1993 eleven per cent of the trees were classed as moderately to severely damaged, i.e. they had lost more than a quarter of their foliation.

Other negative effects caused by the sulphur and nitrogen pollution are changes in the flora and fauna, acidification of the groundwater, reduced crop yields, damage to materials and cultural monuments, and direct impact on human health.

The cause of acidification is to be found in man-made emissions to the atmosphere, primarily of sulphur dioxide and nitrogen compounds. As shown by data from the European monitoring program, between 80 and 90 per cent of the sulphur and oxidized nitrogen compounds that are deposited over Sweden comes from abroad, the countries contributing the most being Germany, Britain, and Poland.

The discovery of the acidification problem in Sweden, in the mid-1960s, led to the adoption of measures to reduce the emissions of sulphur dioxide, starting in 1969. In 1970 Swedish emissions of sulphur dioxide amounted to about 900,000 tons. By 1980 they had been nearly halved, and by 1991 thay had fallen to 102,000 tons – a reduction of 80 per cent as compared to the level of 1980. Parliament has decided that the aim will be to reduce emissions by 80 per cent between 1980 and 2000.

Swedish emissions of nitrogen oxides amounted in 1980 to 425,000 tons, and by 1992 they had been reduced by 10 per cent, to 384,000 tons. The target for reductions as decided by the Swedish parliament is to reach a 30-per-cent reduction by 1995. According to estimates by the Swedish Environment Protection Agency, this target is however not likely to be attained until around 2000.

The amount of acid deposition that that various types of soil will manage to neutralize in the long run – the so-called critical load – will depend primarily on the mineral weathering rate. The critical load may be defined as the greatest superaddition of a certain pollutant an ecosystem can support without suffering damage in the long term. The additions of acid substances should therefore not take place at a rate exceeding that required for enabling soil weathering to neutralize them.

In Scandinavia, the critical loads for acid deposition are being exceeded on 80 per cent of the forest area. According to recent calculations done by the Swedish Environment Protection Agency, for Sweden the deposition will have to be reduced by at least 70 per cent between 1990 and 2010 if the acidification of the soil is not to go on increasing. To reverse acidification will naturally require still greater reductions. And the quicker the desired rate of recovery, the faster and greater they must be.

The Swedish
NGO Secretariat
on Acid Rain

About the secretariat

The Swedish NGO Secretariat on Acid Rain was formed in 1982 and has a board consisting of one representative from each of the following organizations: The Environmental Federation, the Swedish Anglers' National Association, the Swedish Society for Nature Conservation, the Swedish Youth Association for Environmental Studies and Conservation, and the World Wide Fund for Nature Sweden.

The essential aim of the secretariat is to promote awareness of the problems associated with air pollution, and thus, in part through public pressure, to bring about the required reduction of the emissions of air pollutants. The eventual aim is to have those emissions brought down to levels – the so-called critical loads – that the environment can tolerate without suffering damage.

In furtherance of these aims, the secretariat operates as follows, by

☐ Keeping under observation political trends and scientific developments.

☐ Acting as an information centre, primarily for European environmentalist organizations, but also for the media, authorities, and researchers.

☐ Publishing a magazine, Acid News, which is issued five times a year and is distributed free of charge to some 5000 selected recipients.

☐ Producing and distributing information material.

☐ Supporting environmentalist bodies in other countries by various means, both financial and other, in their work towards common ends.

☐ Acting as coordinator of the international activities, including lobbying, of European environmentalist organizations, as for instance in connection with the meetings of the bodies responsible for international conventions, such as the United Nations Convention on Long Range Transboundary Air Pollution.

☐ Acting as an observer at the proceedings involving international agreements for reducing emissions of greenhouse gases.

The work of the secretariat is largely directed on the one hand towards eastern Europe, especially Poland, the Baltic States, Czech Republic, Slovakia, and the western part of Russia, and on the other towards members of the European Union, in particular Great Britain. By emitting large amounts of sulphur and nitrogen oxides, all these countries add significantly to acid depositions over Sweden.

As regards the eastern European countries, activity mostly takes the form of supporting and cooperating with the local environmentalist movements. Since 1988, for instance, financial support has been given towards maintaining information centres on energy, transport, and air pollution. All are or will be run by local environmentalist organizations.