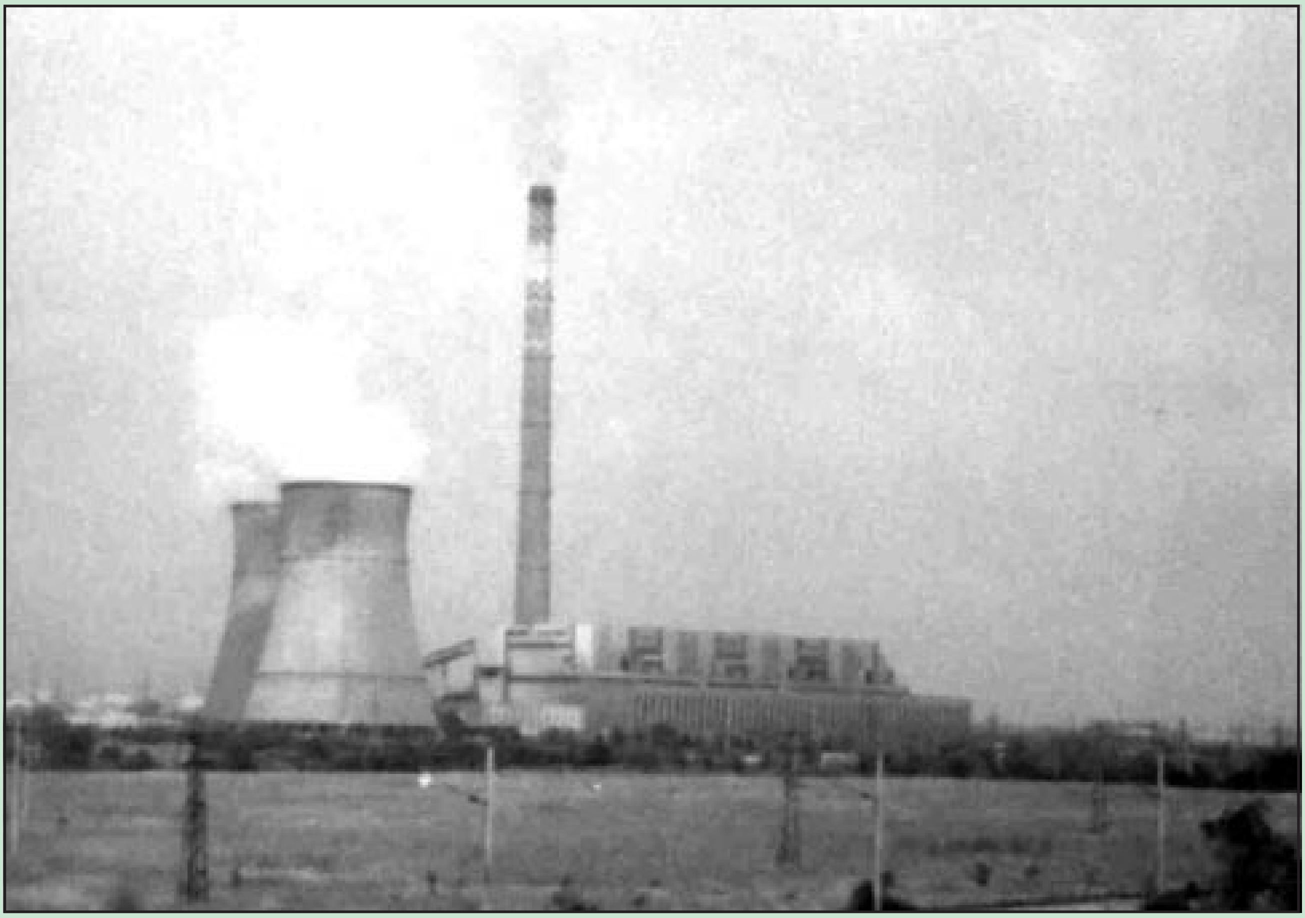
AIR POLLUTION AND CLIMATE SERIES

15

The worst and the best

Atmospheric Emissions from Large Point Sources in Europe



By
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AIR POLLUTION AND CLIMATE SERIES

The worst and the best. Atmospheric Emissions from Large Point Sources in Europe

By Mark Barrett, SENCO, Sustainable Environment Consultants Ltd, 23 A Inglis Rd, Colchester,
Essex CO3 3HU, UK. Tel: +44 (0)1206 761445. E-mail: MarkBarrett@SENCOUK.co.uk

Cover illustration: Maritsa power plant, Bulgaria. © Kliment Mindjov.

ISBN: 91-973691-5-2

ISSN: 1400-4909

Printed by Williamssons Offset, Solna, Sweden, 2000.

Published by the Swedish NGO Secretariat on Acid Rain, Box 7005,
S-402 31 Göteborg, Sweden. Phone: +46-31-711 45 15. Fax: +46-31-711 46 20.
E-mail: info@acidrain.org. Internet: www.acidrain.org.

Further copies can be obtained free of charge from the publisher, address as above.

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Acknowledgement

SENCO would particularly like to thank Christer Ågren (Director of the Swedish NGO Secretariat on Acid Rain) who wrote the introduction to this study, and for his help with collating information about the sources. This work was funded by the Swedish NGO Secretariat on Acid Rain. Mark Barrett of SENCO takes responsibility for any errors or misrepresentations in the report.

Colchester, September 2000

Mark Barrett

SENCO, Sustainable Environment Consultants Ltd

1. Introduction

1.1. Background

The emissions of sulphur dioxide and nitrogen oxides have significant direct and indirect effects on the environment. These effects include the acidification of soil and water, the eutrophication of terrestrial and coastal ecosystems, the impairment of the natural diversity of flora and fauna, the corrosion of the materials in cultural edifices and structures in general, and harm to human health – the latter primarily through increased levels of ground-level ozone and small airborne particles, such as sulphate and nitrate aerosols.

It is well known that a great part of the emissions of sulphur dioxide comes from a relatively small number of point sources, primarily coal-fired power stations. This was shown in a study made in 1994 (Barrett, Protheroe; 1994) for the Swedish NGO Secretariat on Acid Rain, where it was estimated that between 80 and 90 per cent of the man-made emissions of sulphur in Europe came from the thousand largest point sources, while the hundred worst ones were alone responsible for more than 40 per cent of the total.

In the summer of 1998 the European Commission put forward a proposal for a revision of its Directive for controlling emissions from large combustion plants – the Large Combustion Plants (LCP) Directive. The Commission's own analysis had shown that in the year 2010, 85 per cent of the emissions from large combustion plants of sulphur dioxide in the EU, and 66 per cent of nitrogen oxide emission will come from plants built before 1987. In spite of this the Commission restricted its proposal for the LCP Directive to apply only to new plants.

The European Parliament, however, at its first reading in 1999 voted for extending the LCP Directive to cover all existing large combustion plant of all ages. To give owners of existing plants time to adjust to the new requirements, it proposed a respite of five years – i.e. the requirements should not begin to apply until 2005. This respite could very well be used to reduce the demand for electricity, or to install new, much more efficient and cleaner units. This would in turn make it possible to close down a number of old, inefficient and highly polluting plants, with a consequent gain by way of eliminating much of the emissions of the air pollutants that are damaging to health and the environment, but also with the benefit of cutting down emissions of the chief greenhouse gas, carbon dioxide.

Moreover, the Commission's proposal for revision has been criticised because the emission limit values (ELVs) proposed for new large combustion plants were considered to be far higher than what can already be attained by current techniques. This has been demonstrated (Hjalmarsson; 1996) by the fact that already five years ago there were a large number of plants in operation in EU member states that easily surmounted the proposed requirements. These plants were of various age and size, and fired by a variety of fuels. Several of them recorded emission levels that were already considerably lower than the limit values proposed by the Commission for plants coming into operation after 2003.

The aim of this study is to provide an update to the two above mentioned earlier studies. The results demonstrate that large point sources still are responsible for an overwhelming part of the European emissions of sulphur dioxide. It is estimated that the 100 largest ones alone emit more than eight million tons sulphur dioxide, which is about 40 per cent of the total in 1997. Of these 100 largest sulphur emitters, 83 are coal-fired power stations. When ranking the power stations by increasing pollution (the sum of sulphur dioxide and nitrogen oxides emissions), it is shown that a large number of plants in operation have emission levels that are much lower than the limit values proposed by the Commission for new plants, i.e. plants that are to come into operation after 2003.

This analysis should be taken in account when making policy to control these pollutants and their associated impacts, both in the EU as it now is, and for the medium term future when other countries will have joined the EU. Many of the accession EU countries, as well as some of the current EU member states, have a high proportion of inefficient plants without advanced emission controls using low quality domestic coal. In addition, many of the accession countries may also have less scope for investment. One question is what the regulations should be, for example in terms of ELVs, and at the same time taking into account the need of ensuring level competition in a widening market for electricity and other fuels. Another question is what fiscal measures, for example a tax on emissions, might be applied to reduce pollution emission.

The Swedish NGO Secretariat on Acid Rain argues that a simple way to protect both health and the environment, while ensuring level competition in a liberalised electricity market, would be to apply minimum environmental fiscal measures and standards; for example, as taxes and charges on emissions and emission limit values. Each plant would, as a basic principle, have as far as possible to bear its own costs to the environment. The setting of mandatory emission limit values for existing plants would help ensure that at least the oldest and dirtiest plants would be shut down. And those that were kept going would either have to be retrofitted for flue-gas cleaning or fired with cleaner fuels.

1.2. Updated study

This report describes the emissions to the atmosphere of sulphur dioxide (SO_2), nitrogen oxides (NO_x) and carbon dioxide (CO_2) from large point sources in Europe. This is the second version of a report originally published in 1994. The most 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 emissions from coal fired power stations, the dominant source of emissions. Estimates for most other sources remain the same as in the previous study, and therefore they are less reliable because more out of date.

The first part of the report summarises the study and its results. The second part gives details of the research methodology.

1.2.1. Geographical coverage

The region studied includes the European Union and countries bordering it to the east, south and north: these include former ‘Eastern European’ countries, countries previously in the west of the former USSR, Norway, and Turkey. Point sources have been excluded if they are further east than 45° longitude East – this exclusion mainly affects Russian sources. This region contains thirty-eight countries most of which emit significant quantities of atmospheric pollution. The focus here is on current and potential future EU countries, and western and central Europe. Because of this focus, the availability of reliable data, and the need to restrict the amount of results presented, most of the main text analysis excludes Turkey (TUR), Russia (RUS) and the Ukraine (UKR). Table 1 lists the countries covered. The three letter country codes are according to standard ISO 3166.

Table 1. Countries included in study.

Country	Code	Country	Code
Albania	ALB	Lithuania	LTU
Austria	AUT	Luxembourg	LUX
Belgium	BEL	Macedonia	MKD
Belorussia	BLR	Moldova	MDA
Bosnia-Herzegovina	BIH	Netherlands	NLD
Bulgaria	BGR	Norway	NOR
Croatia	HRV	Poland	POL
Czech republic	CZE	Portugal	PRT
Denmark	DNK	Romania	ROM
Estonia	EST	Russia *	RUS
Finland	FIN	Slovakia	SVK
France	FRA	Slovenia	SVN
Georgia *	GEO	Spain	ESP
Germany	DEU	Sweden	SWE
Greece	GRC	Switzerland	CHE
Hungary	HUN	Turkey	TUR
Ireland	IRL	Ukraine	UKR
Italy	ITA	United kingdom	GBR
Latvia	LAT	Yugoslavia	YUG

* only sources west of 45° longitude East

1.2.2. Point sources and data accuracy

Table 2 below summarises the categories of point source and a summary of data availability and vintage. The older the data, the less likely they are to accurately represent the situation in 2000. In general SO_2 and NO_x emissions have declined in the EU because of environmental controls such as the LCP Directive; and in Eastern Europe because of economic change, changes in fuel mix, and emission control. Therefore in general, the older the data the more likely current emissions will be overestimated. However, as will be seen, coal fired power stations dominate

Table 2. Summary of data sources.

Source		Data years	Sources
POWER STATIONS	Coal	1995-1997	IEA
	Other	1990-1999	Utilities
OTHER	Refineries	1990-1995	Various
	Heat plants	1990-1995	Utilities
	Iron	1980-1990	Various
	Smelters	1980-1999	Various
	Industry	1980-1994	Various

emissions of the pollutants concerned and the data is most recent and accurate for these sources.

Because of the rapid and continuing political and economic change in Eastern Europe and Russia, even recent historic data will often not accurately reflect the situation in 2000. The downturn in production from heavy industries in Eastern Europe and the rapid shift to gas and imported coal in some of the more western countries has brought 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, some of the point sources in the databases have not yet been properly reallocated from the former Yugoslavia and former USSR to their new constituent countries. Therefore data for the newer states, such as Slovenia, Croatia, Bosnia-Herzegovina, 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.

2. Results

Section 2 presents the estimated emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x) and carbon dioxide (CO_2) from Large Point Sources in various ways, as:

- A fraction of total emissions from the ECE region
- A list of the 100 largest SO_2 emitters
- Maps of the largest SO_2 emitters
- SO_2 emissions by age of power plant
- The 200 best fossil power stations

To minimise the size of the tables it has been necessary to shorten plant names: and to use acronyms for emission control equipment (see Table 10 on page 23); and for operators and utilities (see Table 15 on page 35).

2.1 Large point source as a fraction of regional emission

Table 3 summarises emission data for the regions, and for all the point sources in the geographical region recorded in the database (about 3000 point sources). Each pollutant has three columns: the first is the country total; the second is the percentage of country emissions accounted for in the Large Point Sources (LPS) database; and the third is the total from LPS. Country total data are taken from the EMEP programme (Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air pollutants in Europe) which gives historical data for most countries with the most recent data being for 1997 (EMEP, 2000).

In some instances the sum of all sources in the database is more than the country total – this is marked with emboldened text. In general, the reason for overestimation is the age of the historic emissions data. For the countries with small emissions (e.g. Finland, Norway), large proportionate discrepancies can be caused by errors in a small number (even single) point sources – i.e. one major plant closing or having emission control fitted can reduce the discrepancy. The most serious discrepancies are:

- Eastern Europe (the Czech Republic in particular). This is probably due to the age of the data; total SO_2 emissions for this country have fallen by about 55% since 1989.

Table 3. Summary of emission.

	SO_2 kt			NOx kt			CO_2 kt		
	Total	LPS/ Total	LPS	Total	LPS/ Total	LPS	Total	LPS/ Total	LPS
ALB		-	4		-	0		-	0
AUT	57	41%	23	172	5%	8	62	12%	8
BEL	216	62%	133	310	16%	48	122	12%	15
BGR	1365	62%	845	225	58%	131	63	41%	26
BIH	480	1%	5	-	-	0	-	-	0
BLR	208	18%	38	189	0%	0	61	0%	0
CHE	26	28%	7	125	0%	0	45	0%	0
CZE	701	**132%**	928	423	44%	185	130	26%	34
DEU	1468	47%	695	1803	16%	286	894	24%	218
DNK	109	11%	12	248	0%	1	63	1%	0
ESP	1927	49%	947	1243	27%	336	279	26%	72
EST	101	79%	79	15	20%	3	-	-	1
FIN	100	**126%**	126	260	36%	93	65	38%	24
FRA	947	24%	229	1695	1%	15	396	3%	12
GBR	1660	73%	1213	1835	30%	550	579	31%	179
GEO	-	-	22	-	-	0	-	-	0
GRC	543	55%	301	374	33%	122	92	25%	23
HRV	80	13%	10	74	2%	2	20	9%	2
HUN	657	71%	464	198	24%	48	64	27%	17
IRL	165	48%	79	124	26%	33	36	27%	10
ITA	1322	60%	791	1768	4%	74	416	9%	39
LTU	77	0%	0	57	7%	4	19	26%	5
LUX	8	70%	6	22	1%	0	7	2%	0
MDA	17	0%	0	30	0%	0	-	-	0
MKD	17	50%	8	6	34%	2	-	-	1
NLD	124	91%	113	470	22%	105	187	28%	52
NOR	30	**104%**	31	222	1%	2	41	5%	2
POL	2181	52%	1137	1114	60%	665	366	37%	134
PRT	373	34%	127	407	14%	57	67	18%	12
ROM	912	32%	295	319	18%	57	121	10%	13
RUS	2449	**145%**	3560	2379	37%	873	1500	23%	342
SVK	202	89%	179	123	18%	23	45	11%	5
SVN	120	29%	34	71	4%	3	16	4%	1
SWE	69	57%	39	280	2%	4	56	4%	2
TUR	354	**195%**	691	692	30%	208	184	18%	33
UKR	1132	**152%**	1722	455	**157%**	713	-	-	181
YUG	522	68%	355	66	**201%**	133	-	-	28
Total	**20719**	**74%**	**15324**	**17794**	**27%**	**4785**	**5996**	**25%**	**1492**

- Turkey: the discrepancy may be due to the latest country total reported to EMEP being for 1986.
- Russia: the EMEP figures for refer to emissions in European EMEP area only.
- Yugoslavia: EMEP data for stationary sources only, some of the LPS may not have followed the changes in political boundaries.

2.2. Largest sulphur dioxide emitters

Table 4 show the largest 100 emitters in the region ordered by increasing SO_2 emission. (The list in Appendix A shows the largest 100 emitters in the whole of Europe, i.e. including Russia, Ukraine and Turkey.) Emissions of nitrogen oxides (NO_x) and carbon dioxide (CO_2) are also given for power stations. Estimates for these pollutants are not given for other plant types, although in general these plants emit both of these pollutants.

The type of plant is given along with the emission estimate for a given year. Sources of the same type are aggregated by site name or sometimes by town name. These 100 sources make up 64% of the total SO_2 emission for all 3000 point sources, including those in Turkey, Russia and the Ukraine.

Of the largest 100 sources as shown in Table 4, 80 are power stations. All these power stations are fuelled with coal except the Estonian Eesti and Balti power stations which are fuelled with oil shale. The five largest sources, Maritsa II (BGR), Maritsa III (BGR), Puentes As Pontes (ESP), Belchatow (POL), Nikola Tesla (YUG) and Thierbach (DEU) are coal fired power stations and they make up about 20% of total emission from the top 100.

In the top 100 we find eight refineries, seven industries, three smelters and two iron works. Note that the age of data for these sources means their more recent emissions will probably be lower. In consequence the top 100 LPS would probably be further dominated by power stations if more recent data were obtained.

Table 4 gives estimates of carbon dioxide emission for most power stations expressed in Mt CO_2. Carbon emission estimates for other plant types have not been estimated. In total the power stations in the top 100 are estimated to emit some 400 Mt CO_2 (million tonnes of carbon dioxide).

To minimise the size of the tables it has been necessary to shorten plant names: and to use acronyms for emission control equipment (see Table 10 on page 23); and for operators and utilities (see Table 15 on page 45).

Table 4. 100 largest SO_2 emitters.

N	Cou	Name (agg)	Type	Out	Fuel	Operator	SO_2 kt	NO_x kt	CO_2 Mt
1	BGR	Maritsa II	PS	E	Cpf	NEK	291	41	8
2	BGR	Maritsa III	PS	E	Cpf	NEK	220	31	6
3	ESP	Puentes As Pontes	PS	E	Cpf	ENDESA	216	56	11
4	POL	Belchatow	PS	EH	Cpf	EB	212	145	25
5	YUG	Nikola	PS	E	Cpf	ES	156	80	15
6	DEU	Thierbach	PS	E	Cpf	VEAG	141	7	3
7	GRC	Irini	PS	E	Cpf	PPC	126	12	2
8	HUN	Matra	PS	EH	Cpf	MVMR	123	22	5
9	GBR	Drax	PS	E	Cpf	NatPow	122	65	24
10	GBR	West Burton	PS	E	Cpf	EG	113	22	7
11	POL	Turow	PS	EH	C	ET	111	72	12
12	GBR	Cottam	PS	E	Cpf	PowGen	110	18	10
13	HUN	Oroszlany	PS	EH	Cpf	MVMR	110	7	2
14	BGR	Maritsa I	PS	E	Cpf	NEK	96	14	3
15	POL	Adamow	PS	EH	Cpf	PAK	96	17	3
16	GRC	St Demetrious	PS	E	Cpf	PPC	88	37	7
17	GBR	Eggborough	PS	E	Cpf	NatPow	88	16	9
18	ITA	Messina	Ref				85		
19	GBR	Ferrybridge	PS	E	C	PowGen	83	14	9
20	YUG	Kosovo	PS	E	Cpf	ES	81	20	4
21	YUG	Kostolac	PS	E	Cpf	ES	74	19	4
22	POL	Patnow	PS	E	Cpf	PAK	71	42	7
23	IRL	Moneypoint	PS	E	Cpf	ESB	65	22	5
24	POL	Kozienice	PS	EH	Cpf	EK	63	38	7
25	ITA	Priolo/Syracusa	Ref				62		
26	ESP	Compostilla	PS	E	Cpf	ENDESA	60	39	7
27	ESP	Meirama	PS	E	Cpf	UEFSA	59	12	2
28	ESP	Robla	PS	E	Cpf	UEFSA	58	19	4
29	GBR	Fiddler’s Ferry	PS	E	Cpf	PowGen	58	11	7
30	ITA	Cagliari Non Ferrou	Ind				57		
31	PRT	Sines	PS	E	Cpf	EDP	56	38	9
32	GRC	Amynteon-Filotas	PS	E	Cpf	PPC	56	16	3
33	CZE	Chemopetrol(Litvinov)	Ref				55		
34	ROM	Turceni	PS	E	Cpf	RENEL	54	18	4
35	DEU	Lippendorf	PS	EH	C	VEAG	54	4	2
36	GBR	Longannet	PS	E	C	ScotPow	51	19	8
37	ITA	Caltanissetta	Ind				51		
38	ITA	Brindisi	Ind				47		
39	BGR	Bobovdol	PS	E	Cpf	NEK	47	12	2
40	GBR	Didcot	PS	E	C	NatPow	47	9	4
41	CZE	Prunerov	PS	EH	C	CEZ	46	40	7
42	DEU	Nordenham	Smelt.				45		
43	GBR	High Marnham	PS	E	Cpf	EG	45	7	2
44	ITA	Venezia Chem	Ind				44		
45	HUN	Ajka	PS	EH	Cpf	MVMR	43	4	1

Table 4. 100 largest SO_2 emitters (continued).

N	Cou	Name (agg)	Type	Out	Fuel	Operator	SO_2 kt	NO_x kt	CO_2 Mt
46	POL	Pomorzany	PS	EH	Cpf	ZEDO	43	29	5
47	POL	Rybnik	PS	EH	Cpf	ER	41	45	9
48	ITA	Sassari Chem	Ind				40		
49	BGR	Varna	PS	E	C	NEK	40	15	3
50	GBR	Kingsnorth	PS	E	Cpf	PowGen	39	15	6
51	CZE	Opatovice	PS	EH	Cpf	EOA	39	11	2
52	ROM	Craiova	PS	EH	Cpf	RENEL	38	9	2
53	GBR	Blyth	PS	E	Cpf	NatPow	38	15	3
54	ITA	Brindisi	PS	E	Cpf	ENEL	38	4	6
55	CZE	Tisova	PS	EH	Cpf	CEZ	38	9	2
56	ESP	Abono	PS	E	Cpf	HDC	36	24	5
57	ESP	Escatron	PS	E	C	ENDESA	36	2	<1
58	EST	Eesti	PS	E	Ochp		36	6	<1
59	HUN	Borsod	PS	EH	Cpf	AES	33	4	1
60	ROM	Drobeta-Turnu	PS	EH	Cpf	RENEL	32	8	2
61	POL	Ostroleka	PS	EH	Cpf	ZEOs	32	19	4
62	EST	Balti	PS	E	Ochp		32	3	<1
63	POL	Siersza	PS	EH	Cpf	ES	31	15	3
64	BEL	Antwerp	Ref				30		
65	GRC	Kardia	PS	E	Cpf	PPC	30	28	5
66	HUN	Pecs	PS	EH	Cpf	MVMR	30	5	1
67	ESP	Anllares	PS	E	Cpf	UEFSA	30	13	3
68	NLD	Rotterdam	Ref				29		
69	GBR	Alcan	PS	E	Cpf	AA	29	7	3
70	GBR	Ironbridge	PS	E	Cpf	EG	29	17	4
71	GBR	Rugeley	PS	E	Cpf	EG	29	14	4
72	SVK	Novaky	PS	EH	Cpf	SlovE	28	9	2
73	ITA	Taranto steel	Iron				28		
74	ESP	Narcea	PS	E	Cpf	UEFSA	27	17	3
75	GBR	Tilbury	PS	E	Cpf	NatPow	26	8	3
76	NLD	Maascentrale	PS	E	C	EPZ	25	18	3
77	CZE	Ledvice	PS	EH	Cpf	CEZ	25	8	1
78	POL	Krakow	Iron				24		
79	ESP	Ribera	PS	E	Cpf	HDC	24	15	3
80	GRC	Megalopolis	PS	E	Cpf	PPC	24	9	2
81	POL	Lodz	PS	EH	Cpf	ZEL	24	13	3
82	POL	Krakow	PS	E	Cpf	EdF	23	7	2
83	DEU	Mehrum	PS	E	Cpf	KMG	23	4	3
84	ESP	Escucha	PS	E	Cpf	UTSA	23	3	1
85	DEU	Frimmersdorf	PS	E	Cpf	RWE	22	20	19
86	ITA	Cagliari	Ref				22		
87	ESP	Guardo	PS	E	Cpf	Iberdrola	22	11	2
88	POL	Zeran	PS	EH	Cpf	EW	21	12	2
89	POL	Huta Katowice DG	Ind				21		
90	GRC	Ptolemais	PS	E	Cpf	PPC	21	19	4

Table 4. 100 largest SO_2 emitters (continued).

N	Cou	Name (agg)	Type	Out	Fuel	Operator	SO_2 kt	NO_x kt	CO_2 Mt
91	CZE	Melnik	PS	EH	Cpf	CEZ	21	26	5
92	DEU	Gelsenkirchen	Ref				20		
93	BLR	Novo Polotsk	Ref				20		
94	DEU	Goslar	Smelter				19		
95	POL	Elektrownia	PS	EH	C	EJ	19	34	7
96	POL	Skawina	PS	EH	Cpf	ESk	19	12	2
97	FIN	Kokkola	Smelter				19		
98	GBR	Drakelow	PS	E	Cpf	EG	19	10	2
99	GBR	Cockenzie	PS	E	C	ScotPow	19	10	2
100	HUN	November 7th (Inota)	Ind				18		

The importance of good information about parameters such as fuel sulphur content and station operation may be emphasised:

- 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 sulphur content nearer to 500 t/PJ, which is less than a sixth of the sulphur per energy in the fuel.
- The 1998 SO_2 emission for Drax is 122 kt as reported by the UK DETR, whereas an emission of 25 kt is calculated from the IEA data. The difference is because the FGD system was not operating fully in the year of reported emission increasing emission fivefold.

Variations in such factors lead to a ten fold variation in emission per capacity in the top ten power stations as shown in Figure 1: Maritsa emits nearly ten times that of Drax.

Figure 1. Sulphur dioxide emission per installed capacity.

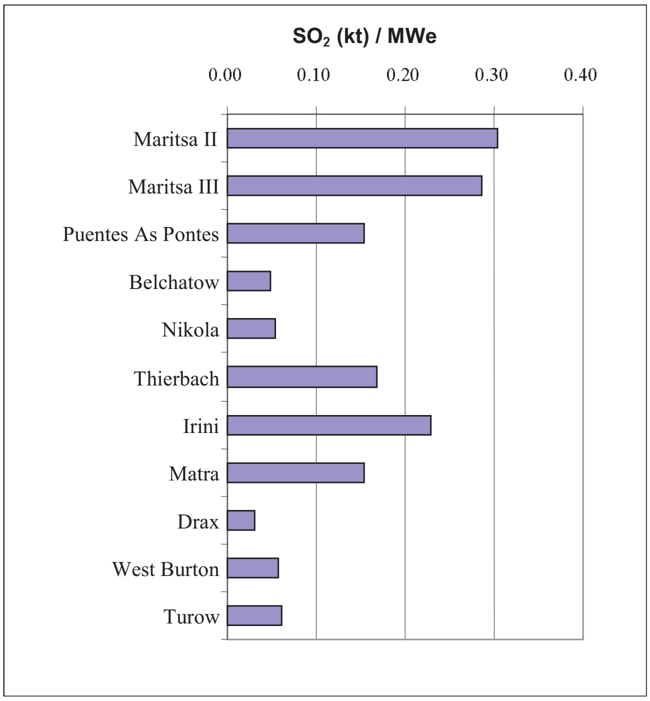
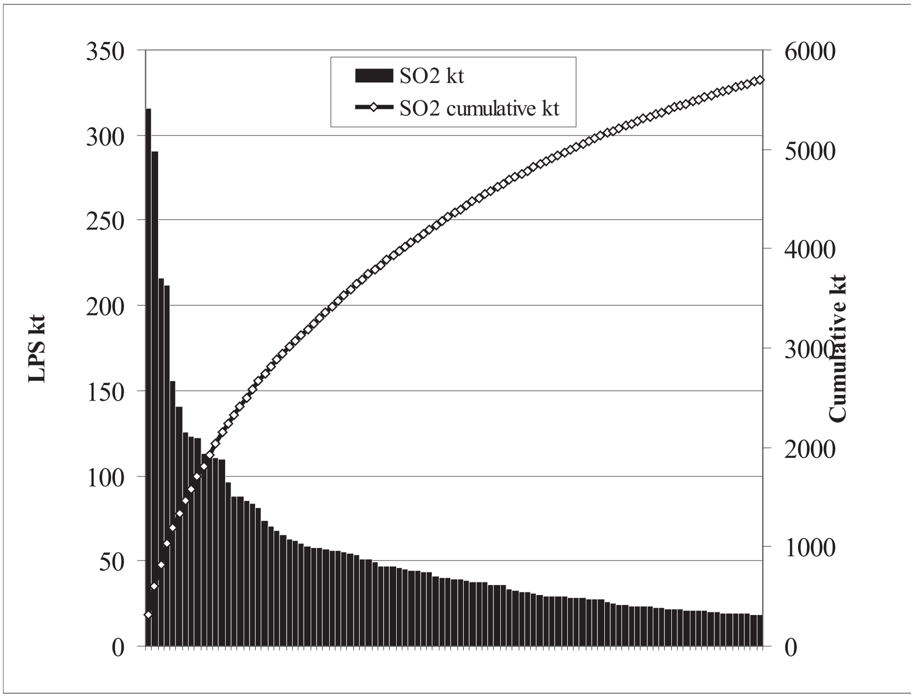


Figure 2 shows the size distribution of the 100 largest sources. It illustrates the importance of the very largest sources.

Figure 2. The 100 largest sulphur dioxide emitters.



2.3. Maps of largest SO_2 emitters

The latitude and longitude of each of the largest 600 SO_2 emitters have been recorded in the database. The LPS database has been input to a Geographical Information System (GIS) in order to map out the spatial distribution of the largest sources. Figure 3 and Figure 4 depict the 600 largest emitters in the whole study area, and the 100 largest in Europe (excluding Russia, Ukraine and Turkey) respectively.

Figure 3. 600 largest SO_2 emitters: whole area.

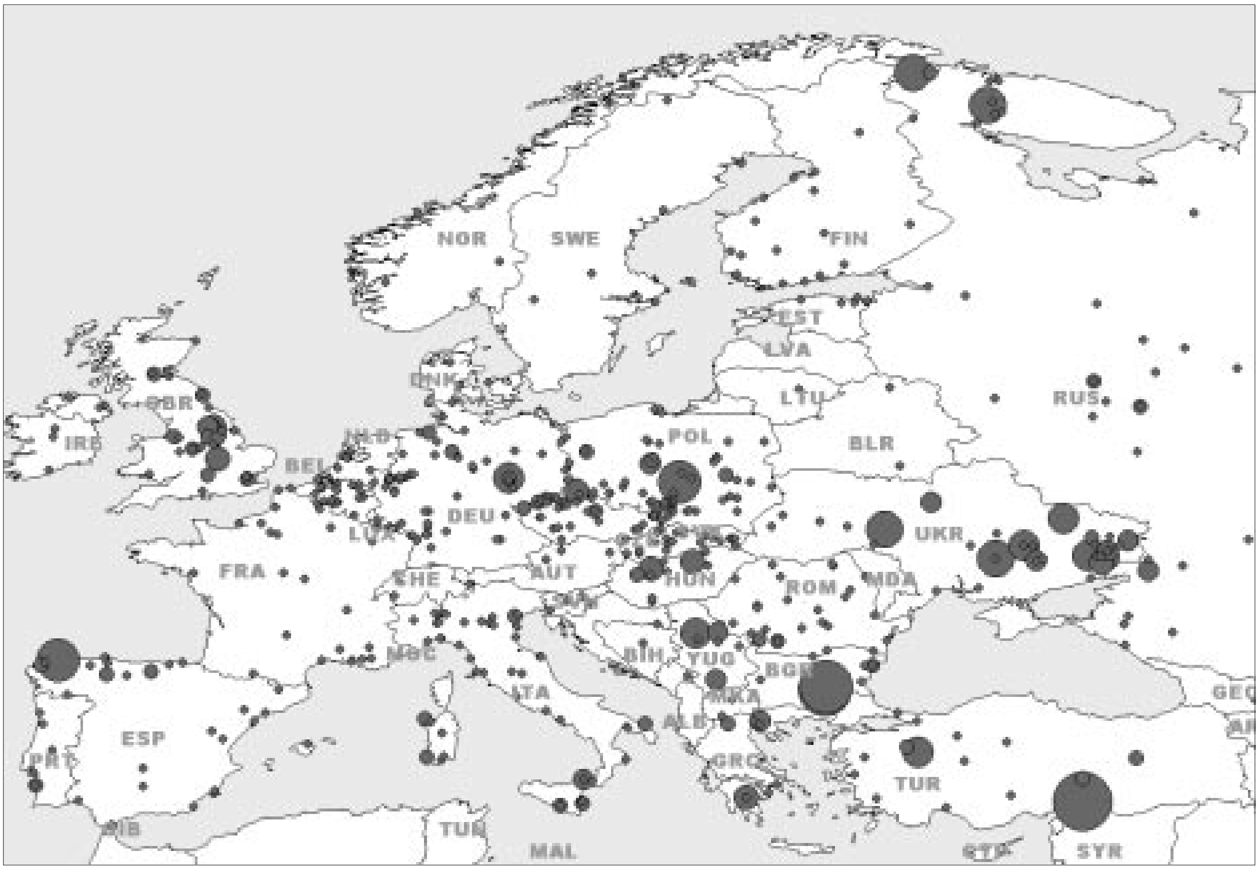
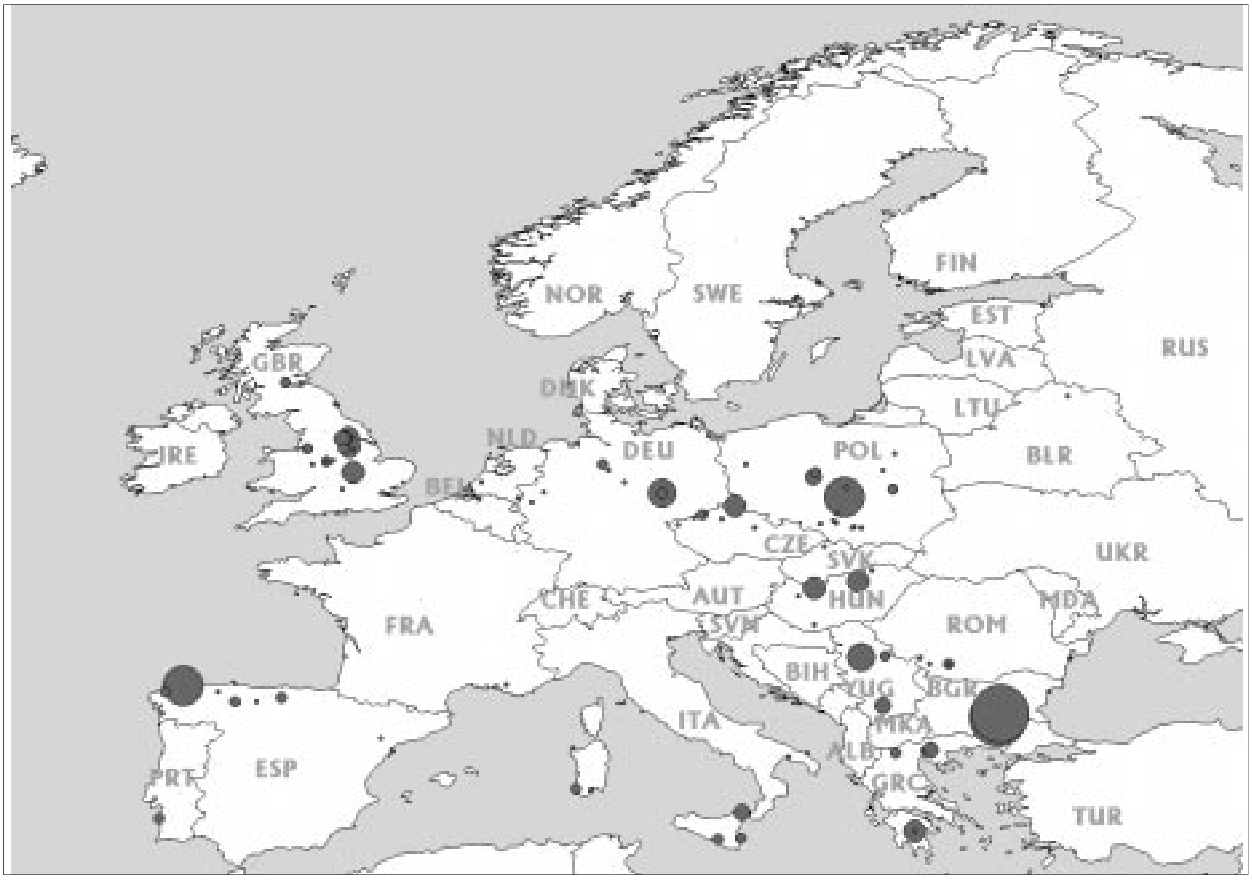


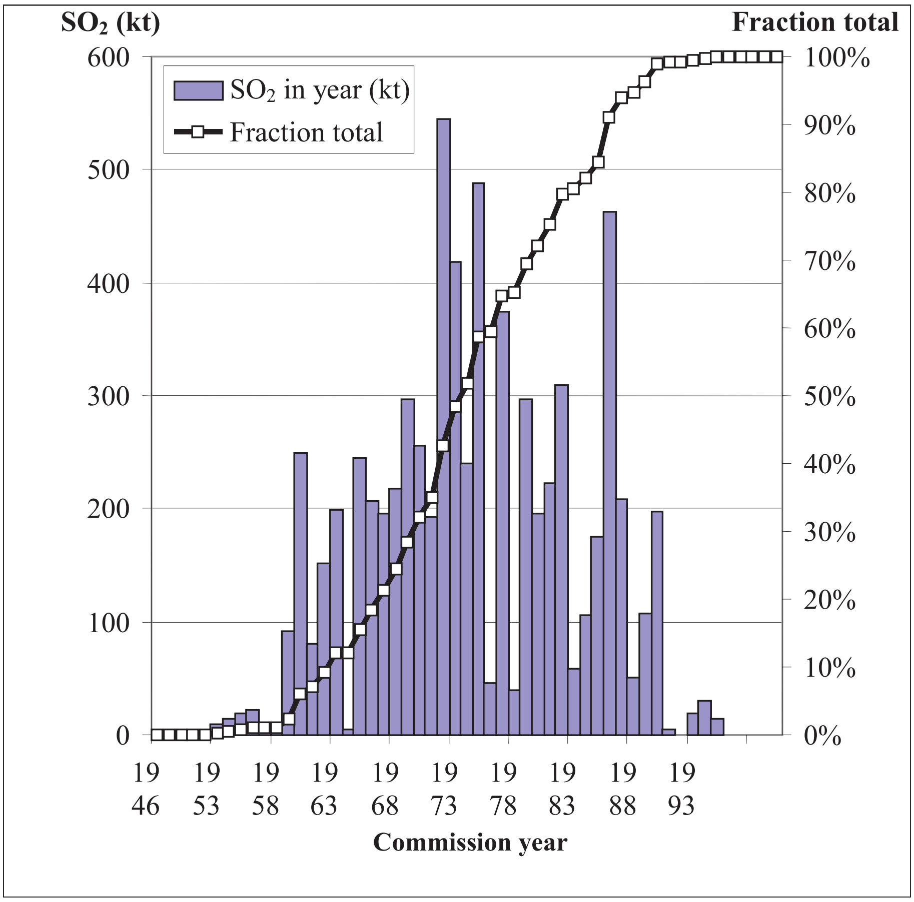
Figure 4. 100 largest SO_2 emitters: Europe not including Turkey, Russia and Ukraine.



2.4. Emissions and age of power plant

Of power stations, coal plants emit the bulk of SO_2 and NO_x. The IEA database gives commissioning dates for most units of most coal plant. The following analysis applies only to those plant for which there are commissioning year data – these plants produce about 62% of total SO_2 emission from power plants. The average of the commissioning year of the first and last plant is taken; on average there is six years difference between the commissioning date of the first and last unit of a plant. The Figure below shows the SO_2 emission for each commissioning year, and the cumulative fraction of emission. Over 90% of SO_2 emission comes from plant commissioned before 1987.

Figure 5. SO_2 emission and commissioning year of power plants.



2.5. Best facilities

The ‘best’ facilities may be defined in terms of atmospheric pollution produced per useful output. The data collated are only adequate to attempt to define these for power stations. It would be possible to compare pollution per output for other facilities: e.g. per tonne of product such as oil, iron, paper – but more data are required. Even for power stations there are significant uncertainties (discussed elsewhere) with the additional problem of estimating heat output for cogeneration plant.

Table 5 lists the 200 best fossil fuelled power stations ordered by increasing pollution per useful output. Pollution is defined as the sum of SO_2 and NO_x emission in kt. Output is the total electricity (E) and useful heat (H) output in PJ. The index, PO, is pollution divided by output. It is emphasised that this Table of results is subject to uncertainties including whether all relevant stations are in the database, fuel sulphur content, efficiencies of conversion from fuel to electricity and heat, and emission control. Where a number of stations have the same PO value because there is inadequate data to make precise emission estimates, they are grouped in an emboldened box.

Best plants are also listed in Appendix B where estimates of pollution concentrations in exhaust gas are compared with EU Emission Limit Values (ELVs) expressed in mg/m^3. This is in order to be able to compare these plants performance with current and proposed EU legislation.

According to fuel type, the best plant generally follows this order from best to worst:

- Natural gas combined cycle – natural gas in Western Europe typically has negligible sulphur content.
- Natural gas steam plant
- Oil plant
- Coal plant

This order is basically determined by the fuel characteristics (e.g. sulphur content) and the plant technology (e.g. steam cycle, turbine, reciprocating). This basic order is modified by:

- **Emission control.** If emission control were applied equally to all fuel types (i.e. with the same degree of basic emission reduction), then the order would not change appreciably. There would be exceptions: for example those plant with very low sulphur coal or oil, or high sulphur retention in coal ash, might be ‘cleaner’ than an oil or gas station.
- **Heat production.** If a plant produces useful heat as well as electricity, then useful energy output is typically increased by 100% to 200%, depending on the heat to electricity ratio, and the emissions per output are reduced accordingly.

In Table 5, for station type: the first capital letters denotes the principal fuels; lower case letters denote technology type – Gcc (Gas Combined Cycle), Cpf (Coal, pulverised fuel). “Auto: Gas CHP” signifies gas fuelled combined heat and power.These plants are generally operated by industries (often called auto producers) to produce electricity for their own use: these plants are often small, and yet in aggregate they produce significant amounts of electricity and heat in some countries.

To minimise the size of the tables it has been necessary to shorten plant names: and to use acronyms for emission control equipment (see Table 10 on page 23); and for operators and utilities (see Table 15 on page 35). Emission control technology codes are given. These are of the form Type, Emission reduction, and installation year.

For example: LSD:R95%:Y1991 signifies a Limestone Spray Dry system removing 95% of flue gas SO_2 commissioned in 1991.

Table 5. 200 best fossil fuelled power stations.

PO	Cou	Plant	Operator	Out	Type	SO_2 control	NO_X control
50	GBR	Derwent		EH	Gcc		
51		Auto: Gas CHP		EH	G		
67	SWE	Västerås	VSKAB	EH	Cpf	LSD:R95%:Y1991	R 92%
78	AUT	Riedersbach	OKA	EH	Cpf	FGDw:R95%:Y1993	R 69%
99		**23 GCC PLANT**		**E**	**Gcc**		
101	DEU	Kiel	PEAG	EH	Cpf	FGDw:R95%:Y1987	R 89%
108	AUT	Duernrohr VKG	VKG	EH	Cpf	LSD:R90%:Y1985	R 86%
117		**22 GAS PLANT**		**E**	**G**		
124	NLD	Gelderland	EPON	EH	Cpf	FGDw:R90%:Y1988	R 90%
124		**88 GAS AND GAS/OIL PLANT**		**E**	**GO**		
128	DEU	Muenchen Nord	SMAG	EH	Cpf	FGDw:R99%:Y1992	R 80%
145	DEU	Hafen Hamburg	HEW	EH	Cpf	FGDw:R93%:Y1987	R 83%
147	DEU	Staudinger	PEAG	EH	Cpf	FGDw:R93%:Y1992	R 88%
147	AUT	Mellach	STEWAG	EH	Cpf	FGDw:R90%:Y1986	R 86%
148	DEU	Schwandorf	Bayern	EH	Cpf	FGDw:R95%:Y1989	R 76%
149	DEU	Tiefstack neu	HEW	EH	Cpf	FGDw:R96%:Y1993	R 80%
151	AUT	Duernrohr EVN	EVN	EH	Cpf	LSD:R90%:Y1986	R 86%
154	DEU	Mannheim	GKWM	EH	Cpf	FGDw:R90%:Y1992	R 85%
154	DEU	Aschaffenburg	Bayern	EH	Cpf	FGDw:R92%:Y1987	R 87%
158	DEU	Gersteinwerk	VEW	EH	Cpf	FGDw:R85%:Y1987	R 90%
164	DEU	Rostock	KNG	EH	Cpf	FGDw:R95%:Y1994	R 80%
164	DEU	Offleben II	BKB	EH	Cpf	WL:R97%:Y1987	R 86%
171	DEU	Scholven	VKR	EH	C	x:R95%:Y1988	R 85%
171	DEU	Heilbronn	EnBW	EH	C	x:R90%:Y1987	R 85%
176	DEU	Neckar	NWEAG	EH	Cpf	FGDw:R85%:Y1997	R 86%
182	DEU	Cuno-Herdecke	EKEMAG	EH	Cpf	LSD:R90%:Y1987	R 86%
192	DEU	Wedel	HEW	EH	Cpf	FGDw:R85%:Y1987	R 86%
209	DEU	Mainz	KMW	EH	Cpf	LSD:R87%:Y1989	R 87%
211	DEU	Hannover	SHAG	EH	Cpf	LSD:R85%:Y1989	R 86%
215	DEU	Sandreuth	EWAG	E	Cpf	LSD:R90%:Y1987	R 96%
217	DEU	Voelklingen (HKV)	SAG	EH	Cpf	FGDw:R85%:Y1989	R 86%
218	FIN	Martinlaakso	VE	EH	Cpf	LSD:R95%:Y1993	R 50%
221	DEU	Zolling-Leiningerwerk	IAAG	EH	Cpf	FGDw:R90%:Y1985	R 79%
226	DEU	Franken II	GKWF	EH	Cpf	FGDw:R90%:Y1986	R 80%
245	DEU	Frankfurt Hoechst	MKAG	EH	Cpf	LSD:R90%:Y1988	R 79%
279	DEU	Herne	STEAG	EH	Cpf	FGDw:R93%:Y1989	R 74%
280	SWE	Uppsala	UEAB	EH	Cpf	LIMB:R90%:Y1985	R 60%
280	DEU	Veltheim	GWG	E	Cpf	FGDw:R94%:Y1987	R 86%
310	DEU	Knepper	VKR	E	Cpf	FGDw:R95%:Y1987	R 93%
313	DEU	Voerde	STEAG	E	Cpf	FGDw:R95%:Y1985	R 86%
320	DEU	Arzberg	EOA	E	Cpf	ACSO2NOx:R95%	R 78%
335	DEU	Chemnitz Nord II	SCAG	EH	Cpf	FGDw:R98%:Y1996	R 30%
339	DEU	Wilhelmshaven	PEAG	E	Cpf	FGDw:R90%:Y1986	R 90%
341	DEU	Farge	PEAG	E	Cpf	FGDw:R92%:Y1988	R 90%
343	DEU	Reuter West	BEWAG	E	Cpf	FGDw:R92%:Y1989	R 86%

Table 5. 200 best fossil fuelled power stations (continued).

PO	Cou	Plant	Operator	Out	Type	SO_2 control	NO_X control
349	SWE	Vaesthamnsverket	HEAB	EH	Cpf	LSD:R90%:Y1986	R 30%
369	DEU	Walsum	STEAG	EH	Cpf	FGDw:R85%:Y1988	R 81%
371	FIN	Suomenoja Espoo	ESO	EH	Cpf	LSD:R85%:Y1991	R 60%
396	AUT	Voitsberg	ODK	E	C	x:R95%:Y1986	R 81%
398	DEU	Werdohl-Elverlingsen	EKEMAG	E	Cpf	FGDw:R94%:Y1988	R 88%
399	DEU	Buschhaus	BKB	EH	Cpf	WL:R98%:Y1987	R 30%
402	DEU	Rudow	BEWAG	E	Cpf	FGDw:R95%:Y1988	R 86%
407	DEU	Heyden	PEAG	E	Cpf	FGDw:R92%:Y1987	R 83%
409	POL	Laziska	EL	EH	Cpf	LSD:R95%:Y1999	R 52%
411	DEU	Reuter	BEWAG	E	Cpf	FGDw:R92%:Y1988	R 86%
413	DEU	Walheim	NWEAG	E	Cpf	LSD:R95%:Y1987	R 86%
418	DEU	Shamrock	VKR	E	Cpf	FGDw:R95%:Y1988	R 86%
422	DEU	Munsdorf Phoenix	MIBRAG	EH	Cpf	FGDw:R95%:Y1996	R 30%
435	POL	Dolna Odra	ZEDO	EH	Cpf	FGDw:R90%	R 45%
438	DEU	West	STEAG	E	Cpf	FGDw:R95%:Y1987	R 86%
444	DEU	Datteln	VKR	E	Cpf	FGDw:R95%:Y1988	R 86%
450	DEU	Westerholt	VKR	E	Cpf	FGDw:R95%:Y1988	R 86%
451	DEU	Boxberg	VEAG	E	Cpf	x:R25%:Y1995	R 19%
462	DEU	Bexbach	SAG	E	Cpf	FGDw:R85%:Y1983	R 84%

If carbon emissions were also considered then the ordering of the best plants would not change significantly – in fact the advantage of natural gas would be even more marked because it has low carbon per energy content, and combined cycle plant are significantly more efficient than steam cycle coal and oil plant. It should be noted that emission control technologies can increase carbon emission per useful output by 1% to 8%.

2.6. 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 analysed the costs and performance of FGD (*Flue Gas Desulphurisation Performance Experience*, 1993). For the common wet scrubbers designs capital costs typically ranged around $220 per kW of electrical output of a power station. The total levelised cost of sulphur removal was about $600 per tonne. These costs vary widely depending on the many factors including station size, site characteristics and fuel costs. According to one supplier, the price of FGD (and other emission control such as SCR) has come down significantly over the last 5-10 years. The typical cost of $220 per kW of ten years ago, would now typically be in the range $80-120 per kW (depending on plant size, fuel type, etc) – i.e. the capital cost has halved. The cost per tonne removed sulphur would be $300-600 per tonne rather than $600 per tonne.

Flue gas treatment systems decrease the efficiency of power stations; wet FGD systems decrease efficiency 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 102 GWe. Fitting FGD to these stations would cost about $10 billion in capital cost. This would reduce sulphur emission by about 4700 kt in the region concerned. This is about 23% of the total in area covered. The total levelised annual cost would be some $2.1 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. A separate study for the Swedish NGO Secretariat on Acid Rain (SNGOSAR/EFTE/EEB, 2000) showed that measures to control CO_2, including energy efficiency and switching to gas, reduce the total cost of SO_2 and NO_x emission control so as to meet emission ceilings. The energy scenario for this, including the power sector, was developed by SENCO (*An Alternative Energy Scenario for the European Union*). The scenario incorporated significant changes to electricity consumption because of end use efficiency, and a switch from coal to gas. These measures would have a large effect on the coal power station emissions in the LPS database.

3. Research methodology

The work carried out was divided into four phases:

1. Collection of basic data
2. Collation and estimation of emission for individual sources
3. Aggregation of point sources
4. Reporting including the presentation of tables and maps of largest emitters

The largest 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 are coal fired power stations. A few of the other source types – such as refineries and smelters – are large emitters.

3.1. Data sources

There is 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 have added to the difficulties.

A number of sources of data were investigated – these included:

- Previous data collated by SENCO over 1988-1994 served as the foundation for the power station database. The IEA has produced a database of coal fired power stations with data from 1995-1997, and this has been used extensively (IEA, 2000). This was supplemented with EURELECTRIC information on application of Member States of Directive 88/609.

- Reporting to EU under LCP Directive. 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). It was not possible to obtain these data from the Commission within the time frame of the study, but the UK DETR provided UK data directly to SENCO.
- Industry sources – some information on FGD in Eastern Europe was provided.
- Government sources for Germany, the Netherlands and Austria.
- The databases used for the previous study, incorporating information from the International Institute for Applied Systems Analysis (IIASA), Imperial College and the Stockholm Environment Institute at York (SEIY) were extensively used.

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.

Recorded data

Recorded emission data are those estimates of past emissions made by other, usually official, bodies. Recent emission data have been collated for the larger power stations in Austria, Great Britain, and Estonia. These have been supplemented with other data as available. Where these data are later than 1996 they have been used in preference to calculated emissions.

3.1.1. Classification of point sources

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

3.1.2. Plant name and spatial location

The name of the plant is generally the key to identification. In many 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.

The stages of estimating location were as follows:

- For some point sources longitude and latitude were given in the basic data collected.
- 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 IEA power station database gives the nearest town. SENCO has 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 because large point sources are rarely sited near the centre of towns. 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.

3.1.3. Aggregation

Data for the recorded or calculated emissions are in most cases given for each plant. However it is not easy to define what one plant is. For example, many electricity production sites have several units (boilers and turbogenerators) built over a period of years. These units may be different in design, fuels used and the application of emission control technology such as flue gas desulphurisation (FGD). One or more boilers may share a stack or chimney. Separately owned or operated refineries are often located close to each other.

Definitions of an LPS could include:

- Each stack is an LPS.
- Each stack clustered within a certain distance radius may be aggregated to an LPS.
- Owner and operator at a site to an LPS aggregate stacks.

In general the databases do not contain the fine grain information about stacks shared and spatial location such as is required to reliably and accurately aggregate individual sources to LPS. In this study the emissions from individual units and stations are usually aggregated by site name to give point sources, which in many cases comprise more than one unit or plant.

Power stations are aggregated by names given in the IEA database, power stations using other fuels are also aggregated by names, but are *not* aggregated with the coal stations even if they share the same name and site.

This process of aggregation is generally adequate for concerns of long distance pollution transport. However it is not always adequate for local atmospheric pollution concerns, or for legislation, which might apply to single sources such as the LCP Directive.

3.1.4. Estimated emissions for year

There are limited data detailing historical emissions from individual sources; and of course these are all more or less accurate estimates made by government departments, industry, consultants and so on.

Calculations have therefore been extensively used to estimate emissions. It has not been possible to use the most sophisticated modelling techniques given the resources allocated to this study. The emission of the point sources depends on three basic factors: plant output, the pollutant contents of inputs (e.g. sulphur in coal), and the application of emission control equipment. The emission of a source can vary widely from year to year if one or more of these factors change:

- **Varying production.** For different reasons the production from any particular source can 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 in the next. This may be because other plant are not available: for example, drought and nuclear power problems in France may decrease hydro and nuclear output, and fossil power stations have to be used more extensively. Alternatively product demand may fluctuate because of economic activity.
- **Fuel or input change.** The pollutant 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.

- **Emission control.** The application of emission control such as flue gas treatment to remove SO_2 or NO_x typically reduce emission by 80-95%. The emissions from a plant will correspondingly be reduced when such controls are installed; or increased if the controls are not functioning because of maintenance or breakdown.

Because of uncertainties in these factors the estimates of emissions 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. In the available historic emission data for particular plant very significant decreases and increases are seen.

3.2. Power station emissions

3.2.1. Data

Previous work by SENCO resulted in a database of some 1200 individual power stations for the region covered by this study. This is summarised in the table below. Note that many stations are capable of using more than one fuel. The heat capacity refers to the thermal output used for district and other heating.

Table 6. Power station database.

Type	Number	Electric (GWe)	Heat (GWt)
Coal	578	294	26
Oil	323	136	1
Gas	104	57	2
Nuclear	151	168	0
Renewable	34	83	0
Other	66	3	0
Total	**1256**	**741**	**29**

3.2.1.1. Coal stations

The IEA (UK) produces a database of power stations using coal, with or without other fuels (IEA, 1997). The database only covers stations, which can burn coal and so does not include stations fired only with oil or gas, 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. SENCO has used the 2000 version of this database, which contains data relating to the period up to 1998.

The IEA database gives information about whole power station, and about the individual units making up that station.

The IEA database includes information on:

- Electrical and thermal capacity in MW by unit; but not electrical or heat energy output, or efficiencies.
- Type of boiler by unit.
- Coal consumption, coal thermal and sulphur content, coal source, fraction of energy met with coal (if other fuels used) by station.
- Emission control for SO_2, NO_x and PM by unit.
- Nearest town, utility or operator.

It should be noted that coal burn is given for the whole station, but not for each unit. Therefore when coal burn is less than maximum, there is a question as to which units the coal is burnt in. In general, given choice, the operator will use the coal in the units with lowest marginal cost and producing the least emissions. The approach taken here is to assume that coal is burnt equally in each power station unit pro rata to the electrical output. Similarly, the average emission control pollution removal fraction is calculated by a weighted fraction across all operating units.

3.2.1.2. Non coal stations

For non coal stations, the data are older and less comprehensive – there is no public database for non coal stations comparable to that of the IEA. 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.

3.2.2. Sulphur dioxide emission

Sulphur dioxide emission is calculated as follows:

Emission = (fuel burn) (sulphur in fuel)
x (1- % sulphur retained in ash)
x (1- % sulphur removed by emission control) tonnes sulphur

The percentage of sulphur in the fuel emitted depends on how much is retained by ash (coal stations only), and how much is removed by emission control equipment. Emission calculations for coal and other stations are detailed below.

Emission control equipment and its application is described in 3.2.4.

Coal stations

The IEA database gives figures for coal burn in Mt, the thermal content of coal (GJ/tonne), and coal sulphur content.

For coal boilers, emissions depend on boiler type – Dry Bottom Boiler (DBB) and Wet Bottom Boiler (WBB), described as follows. The DBB is characterised by the dry ash discharge from the combustion chamber due to combustion temperatures from 900 up to 1,200 °C. This type of boiler is mainly used for the combustion of hard coal and lignite and is applied all over Europe. The WBB has typical combustion temperatures exceeding 1,400 °C lead to a liquid slag discharge from the combustion chamber. This type of boiler is used for hard coal with a low content of volatiles and is mainly applied in Germany.

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 (e.g. how alkaline it is) and on combustion conditions. 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%. Retention factors are summarised in Table 7.

The IEA database records emission control equipment as applied to each unit of a power station. This can include type of equipment and percentage emission reduction. If this latter is not given then a typical figure is assumed.

Non coal stations

Data on the technical and fuel characteristics of non coal stations are generally inferior to the IEA data. This difficulty is compounded by the

Table 7. Sulphur ash retention factors.

Plant	Country	Boiler type	Coal	Retention
		DBB	Hard	5%
		DBB	Brown	30%
		WBB	Hard	1%
	CZE	DBB	Brown	5%
Kardia	GRC	DBB	Brown	70%
Ptolemais	GRC	DBB	Brown	70%

fact that a large proportion of fossil plant can utilise several different fuels; with stations capable of using both oil and gas being common: in such cases, it has been generally assumed that gas rather than oil is used. 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 natural gas typically has a low sulphur content and so assuming gas rather than 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, as it typically the case, it is assumed that the plant has a default efficiency (35% coal, 36% oil, 37% gas steam, 4% gas combined cycle). Default load factors are also assumed (10% oil, 60% gas). Apart from CHP plant, and natural gas plants, non coal fossil stations in Europe are often only used for peak loads, or as a back up when outputs from coal, nuclear and renewable electricity sources are low because of breakdown, maintenance or meteorology.

These factors have been used to estimate fuel burn, and modified only if inconsistent with other information. Table 8 summarises the default emission indices used for non coal power stations. These are based on UK and CORINAIR emission factors.

Table 8. Non coal power station emissions.

	G/GJ fuel	
Type	**SO_2**	**NO_x**
Fuel Oil	1000	190
Natural Gas – combined cycle	8	45
Gas Oil	80	65
Orimulsion	2000	267

3.2.3. Nitrogen oxides emission

Nitrogen oxides are formed from nitrogen compounds in the fuel (fuel NO_x) and from the combination of atmospheric oxygen and nitrogen in the high temperature of the boiler (thermal NO_x). Thus the amount formed depends both on fuel characteristics and on boiler design and operation.

NO_x emission is calculated as follows:

Emission = (fuel burn)
x (emission factor dependent on fuel and boiler)
x (1- % NO_x removed by emission control) tonnes NO_x

Coal stations

The CORINAIR manual (European Environment Agency; 1999) summarises a calculation method for estimating NO_x.

For coal boilers, NOx emission factors (g/GJ) are given for the Dry Bottom Boiler (DBB) and Wet Bottom Boiler (WBB), for various coal types. Table 9 presents the NO_x emission factors from CORINAIR. Where the coal source is not known, the average figures are used.

Table 9. Coal power station NO_x emission factors (g/GJ fuel).

Type	Coal source	DBB	WBB
Hard	**Average**	**481**	**596**
	Australia	568	703
	Canada	500	627
	China	413	512
	Columbia	535	662
	Czech Republic	483	598
	France	374	463
	Germany RAG	384	476
	Germany others	495	613
	Russia	308	382
	Hungary	401	496
	India	551	682
	South Africa	569	705
	USA	563	697
	Venezuela	588	728
Brown	**Average**	**483**	
	Czech Republic	506	
	- Germany Rheinisch Coal	325	
	-Middle Germany	504	
	-East Germany	539	
	Hungary	379	
	Poland	531	
	Portugal	461	
	Turkey	725	

Non coal stations

NO_x emission for non coal stations is calculated using the factors in Table 8.

3.2.4. SO_2 and NO_x emission control technologies

There are a number of processes used for the removal of SO_2 and NO_x separately, and of the two together. Those processes present in the databases are tabulated below with long descriptions and acronyms. The last column gives a figure for the typical percentage reduction in emission brought about by each process if it is applied to all of the combustion and combustion products in a station. It is emphasised that there is a great variation in these reduction figures in practice because of the technicalities of plant design and fuel characteristics. Where station specific data are not provided, the default reductions in Table 10 and Table 11 are assumed.

Some of these processes may be combined, some are mutually exclusive. This is fairly common for NO_x where a 'primary' process, such as boiler firing modification, may be combined with flue gas treatment. Further, there is a range of methods for controlling particulate matter (PM), some of which may be combined with controlling SO_2 and NO_x, but PM emission is not addressed in this study.

The IEA power station database gives specific reductions for many emission control installations that are different from the typical figures. The IEA database gives the application of control measures for each unit of a power station.

Summaries of emission control technologies are given in some of the results tables. These are of the form Type, Emission reduction, and installation year. For example: WL:R 96%:Y1998 signifies a Wellman Lord system removing 96% of flue gas SO_2 commissioned in 1998.

Table 10. SO_2 emission control.

Pollutant	Description	Acronym	SO_2 rem
SO_2	FGD (non-specific)	FGD	90%
	Wet FGD	FGDw	90%
	Hybrid sorbent	HS	82%
	Limestone/gypsum	LG	90%
	Limestone injection	LIMB	50%
	Limestone spray dry	LSD	80%
	Spray dry	SD	80%
	Spray dry lime	SDLime	80%
	Sorbent injection	SI	50%
	Wellman Lord	WL	97%
	Wet lime	WLIM	90%
	LIFAC Dry Sorbent Injection Process	LIFAC	70%
	Circulating fluid bed dry scrubber	CFBDS	80%
	Hybrid sorbent injection	HIS	80%
	Regenerable, magnesium oxide	MgO	80%
	Walther Process (WAP)	WAP	88%
SO_2	Activated Carbon Process (AC)	ACSO2NOx	95%
(& NO_x)	DESONOX Process/SNOX Process	DESONOX	95%
	Combined SO2/NOx, duct sorbent injection	DESONOXDSI	80%
	Combined SO2/NOx, electron beam irradiation	DESONOXElec	80%
	Combined SO2/NOx/particulates, catalytic	DESONOXPMCat	80%

Table 11. NO_x emission control.

Pollu-tant	Description	Acronym	NO_x rem
NO_x	Non specific	NS	45%
	Combust modification	CM	45%
	Low NOx burner	LNB	45%
	Selective catalytic reduction	SCR	90%
	Staged Air Supply	SAS	45%
	Overfire Air	OFA	45%
	Flue Gas Recirculation	FGR	45%
	Combustion modification & SCR	CMSCR	95%
NO_x (&SO_2)	Activated Carbon Process (AC)	ACSO2NOx	95%
	DESONOX Process/SNOX Process	DESONOX	95%
	Combined SO2/NOx, duct sorbent injection	DESONOXDSI	80%
	Combined SO2/NOx, electron beam irradiation	DESONOXElec	80%
	Combined SO2/NOx/particulates, catalytic	DESONOXPMCat	80%

3.2.5. Carbon dioxide emission

Carbon emission is estimated using standard International Energy Agency (IEA) coefficients as applied to fuel burn data and estimates for power stations.

3.3. Emissions from other energy facilities

This section summarise information about emissions from energy facilities other than coal power stations.

3.3.1. Refineries

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.

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

The total country use of crude oil was determined from IEA energy balance tables. This figure was used to adjust the output amongst the refineries according to their nameplate capacities. A base emission factor of 0.5 kg S per 1000 kg crude oil was used unless other data was available. For some countries (e.g. the Netherlands) refinery emissions were adjusted to account for national totals.

3.3.2. 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 Russia and data for this region is difficult to obtain. 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 10 kt SO_2. Several hundred other sources are larger than this.

3.4. Industries

The principal industrial processes separately covered are smelting, pig iron production and wood pulping. In addition there are separate data on general industry. There are very limited data providing accurate estimates of emissions from industry. What data there are however, 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 feedstock and fuels.

Emissions have been calculated for some 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.

3.4.1. General industry

A range of independent emission data sources was used for general industry. This includes UK DETR data and data collated by Imperial College with a focus on central Europe.

3.4.2. Smelters

There is sulphur in some ores and in the fuels used to drive smelting processes. 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.

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). Data for 1998 emissions for a few smelters has been used.

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

3.4.3. 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.

3.4.4. 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.

4. Conclusions

This work on Large Point Sources has updated and improved the information collated in the previous study, more especially through the more thorough analysis of emissions from coal power stations. These observations may be made:

- There has been a significant reduction in SO_2 and NO_x emissions from LPS since the previous study. In Western Europe, this is mainly because of the application of flue gas treatment and the switch to lower sulphur fuels; further east these changes have also occurred, but economic restructuring has also been an important factor.
- Coal power stations still dominate emissions from LPS.
- Old plants, i.e. those commissioned before 1987, are responsible for more than 90% of total European SO_2 emission from power stations.
- It is clear that an increasing fraction of emissions will come from eastern countries, some of which will join the EU in the forthcoming years.

4.1. Further work

4.1.1. Updating and extending information

- Integration of databases. Keeping large databases up to date requires effort. This effort is minimised by using other pre-existing databases as far as possible.
- Integration with other programmes. Perhaps the most important in this context is to make use of the emission reporting carried out under the LCP directive. In addition there are LPS databases used by bodies such as IIASA and EMEP.
- Extending to other pollutants. Many of the LPS are significant sources of atmospheric pollutants other than SO_2, NO_x and CO_2. These include: particulate matter with a certain fraction in the 2.5 to 10 μm range, in some cases associated with toxic metals and other chemicals; carbon monoxide, nitrous oxide and volatile organic compounds including methane.

4.1.2. Use of data in policy formulation

LPS are important for policies to control SO_2, NO_x and CO_2. LPS constitute a large faction of total emissions; they can raise local concentrations above air quality limits; as well as contributing to long range pollution.

- Emission control technologies for LPS are generally relatively cheap because of economies of scale.
- Application and monitoring of emission control legislation is relatively simple because of the small number of plants.
- There is potential for emissions trading between LPS operators because the overheads are proportionately lower than for small sources.

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APPENDIX A

Largest 100 SO_2 emitters: All countries

Table 12 lists the largest 100 SO_2 emitters including those in Turkey, Russia and the Ukraine. This changes list of the largest 100 significantly: 26 of the 100 are from the three previously excluded countries. The list is still dominated by coal fired power stations, but some of the Russian smelters in the Kola peninsular appear in the largest 100.

Table 12. 100 largest SO_2 emitters: including TUR, RUS, and UKR.

N	Cou	Name (agg)	Type	Out	Fuel	Operator	SO_2 kt	NO_x kt	CO_2 Mt
1	TUR	Afsin Elbistan	PS	E	Cpf	TEK	350	48	6
2	BGR	Maritsa II	PS	E	Cpf	NEK	291	41	8
3	BGR	Maritsa III	PS	E	Cpf	NEK	220	31	6
4	ESP	Puentes As Pontes	PS	E	Cpf	ENDESA	216	56	11
5	POL	Belchatow	PS	EH	Cpf	EB	212	145	25
6	UKR	Krivorozhskaya	PS	E	C	DnepE	205	106	23
7	UKR	Lodyzhinskaya	PS	E	Cpf	VinnE	193	70	19
8	RUS	Nikel	Smelter				189		
9	UKR	Zuevskaya	PS	E	C	DonbE	164	61	15
10	UKR	Zmiyevskaya	PS	E	C	KharE	161	81	19
11	UKR	Kurakhovskaya	PS	E	C	DonbE	159	57	12
12	YUG	Nikola	PS	E	Cpf	ES	156	80	15
13	TUR	Seyitomer	PS	E	Cpf	TEK	149	29	4
14	UKR	Pridneprovskaya	PS	E	C	DnepE	146	76	19
15	DEU	Thierbach	PS	E	Cpf	VEAG	141	7	3
16	GRC	Irini	PS	E	Cpf	PPC	126	12	2
17	HUN	Matra	PS	EH	Cpf	MVMR	123	22	5
18	GBR	Drax	PS	E	Cpf	NatPow	122	65	24
19	UKR	Starobeshevskaya	PS	E	C	DonbE	121	54	12
20	GBR	West Burton	PS	E	Cpf	EG	113	22	7
21	POL	Turow	PS	EH	C	ET	111	72	12
22	GBR	Cottam	PS	E	Cpf	PowGen	110	18	10
23	HUN	Oroszlany	PS	EH	Cpf	MVMR	110	7	2
24	RUS	Novocherkasskaya	PS	EH	C	RostE	106	39	13
25	UKR	Uglegorskaya	PS	E	C	DonbE	98	45	11
26	UKR	Tripolskaya	PS	E	C	KiyeE	97	44	11
27	BGR	Maritsa I	PS	E	Cpf	NEK	96	14	3
28	POL	Adamow	PS	EH	Cpf	PAK	96	17	3
29	UKR	Luganskaya	PS	E	C	DonbE	92	41	10
30	RUS	Monchegorsk	Smelter				88		

Table 12. 100 largest SO_2 emitters: including TUR, RUS, (Continued).

N	Cou	Name (agg)	Type	Out	Fuel	Operator	SO_2 kt	NO_x kt	CO_2 Mt
31	GRC	St Demetrious:PS	PS	E	Cpf	PPC	88	37	7
32	GBR	Eggborough	PS	E	Cpf	NatPow	88	16	9
33	ITA	Messina	Ref				85		
34	GBR	Ferrybridge	PS	E	C	PowGen	83	14	9
35	UKR	Zaporozhskaya	PS	E	C	DnepE	83	33	6
36	YUG	Kosovo	PS	E	Cpf	ES	81	20	4
37	YUG	Kostolac	PS	E	Cpf	ES	74	19	4
38	POL	Patnow	PS	E	Cpf	PAK	71	42	7
39	RUS	Zapoljarnyj	Smelter				68		
40	TUR	Kangal	PS	E	Cpf	KOCH	67	10	1
41	IRL	Moneypoint	PS	E	Cpf	ESB	65	22	5
42	POL	Kozienice	PS	EH	Cpf	EK	63	38	7
43	ITA	Priolo/Syracusa	Ref				62		
44	ESP	Compostilla	PS	E	Cpf	ENDESA	60	39	7
45	ESP	Meirama	PS	E	Cpf	UEFSA	59	12	2
46	RUS	Mosenergo	PS	EH	C	MosE	58	25	10
47	ESP	Robla	PS	E	Cpf	UEFSA	58	19	4
48	RUS	Ryazanskaya	PS	E	Cpf	RyazE	58	12	4
49	GBR	Fiddler’S Ferry	PS	E	Cpf	PowGen	58	11	7
50	ITA	Cagliari Non Ferrou	Ind				57		
51	PRT	Sines	PS	E	Cpf	EDP	56	38	9
52	GRC	Amynteon-Filotas	PS	E	Cpf	PPC	56	16	3
53	CZE	Chemopetrol(Litvinov)	Ref				55		
54	UKR	Slavyanskaya	PS	E	C	DonbE	55	28	8
55	ROM	Turceni	PS	E	Cpf	RENEL	54	18	4
56	DEU	Lippendorf	PS	EH	C	VEAG	54	4	2
57	GBR	Longannet	PS	E	C	ScotPow	51	19	8
58	ITA	Caltanissetta	Ind				51		
59	ITA	Brindisi	Ind				47		
60	BGR	Bobovdol	PS	E	Cpf	NEK	47	12	2
61	GBR	Didcot	PS	E	C	NatPow	47	9	4
62	CZE	Prunerov	PS	EH	C	CEZ	46	40	7
63	DEU	Nordenham	Smelter				45		
64	GBR	High Marnham	PS	E	Cpf	EG	45	7	2
65	ITA	Venezia Chem	Ind				44		
66	HUN	Ajka	PS	EH	Cpf	MVMR	43	4	1
67	POL	Pomorzany	PS	EH	Cpf	ZEDO	43	29	5
68	TUR	Tuncbilek	PS	E	Cpf	TEK	43	11	1
69	POL	Rybnik	PS	EH	Cpf	ER	41	45	9
70	ITA	Sassari Chem	Ind				40		
71	BGR	Varna	PS	E	C	NEK	40	15	3
72	GBR	Kingsnorth	PS	E	Cpf	PowGen	39	15	6
73	CZE	Opatovice	PS	EH	Cpf	EOA	39	11	2
74	ROM	Craiova	PS	EH	Cpf	RENEL	38	9	2
75	GBR	Blyth	PS	E	Cpf	NatPow	38	15	3

Table 12. 100 largest SO_2 emitters: including TUR, RUS, (Continued).

N	Cou	Name (agg)	Type	Out	Fuel	Operator	SO_2 kt	NO_x kt	CO_2 Mt
76	ITA	Brindisi	PS	E	Cpf	ENEL	38	4	6
77	CZE	Tisova	PS	EH	Cpf	CEZ	38	9	2
78	ESP	Abono	PS	E	Cpf	HDC	36	24	5
79	ESP	Escatron	PS	E	C	ENDESA	36	2	<1
80	EST	Eesti	PS	E	Ochp		36	6	<1
81	RUS	Cherepovetskaya	PS	E	C	VoloE	34	9	3
82	HUN	Borsod	PS	EH	Cpf	AES	33	4	1
83	ROM	Drobeta-Turnu	PS	EH	Cpf	RENEL	32	8	2
84	POL	Ostroleka	PS	EH	Cpf	ZEOs	32	19	4
85	EST	Balti	PS	E	Ochp		32	3	<1
86	RUS	Smolenskaya	PS	E	C	SmolE	31	4	1
87	POL	Siersza	PS	EH	Cpf	ES	31	15	3
88	BEL	Antwerp	Ref				30		
89	GRC	Kardia	PS	E	Cpf	PPC	30	28	5
90	HUN	Pecs	PS	EH	Cpf	MVMR	30	5	1
91	ESP	Anllares	PS	E	Cpf	UEFSA	30	13	3
92	NLD	Rotterdam	Ref				29		
93	GBR	Alcan	PS	E	Cpf	AA	29	7	3
94	GBR	Ironbridge	PS	E	Cpf	EG	29	17	4
95	GBR	Rugeley	PS	E	Cpf	EG	29	14	4
96	TUR	Catalagzi	PS	E	Cpf	TEK	29	7	1
97	RUS	Apatity	Smelt.				28		
98	SVK	Novaky	PS	EH	Cpf	SlovE	28	9	2
99	ITA	Taranto steel	Iron				28		
100	ESP	Narcea	PS	E	Cpf	UEFSA	27	17	3

APPENDIX B

Emission concentrations

The 1988 Large Combustion Plant Directive (88/609/EEC) sets Emission Limit Values (ELVs) for SO_2 and NO_x for new plants – these are expressed as maximum concentrations of pollutants in the exhaust gases in mg/Nm^3. The Commission made a proposal (COM(98)415 final) from July 1998 to amend the 1988 ELVs.

ELVs are specified for SO_2 and NO_x and vary with:

- Combustion fuel: Solid (S), Liquid (L), Gas (G) and Biomass (B)
- Thermal power of fuel input (MWth)

Table 13 shows the 1988 and 1998 ELVs.

Table 13. Large combustion plant emission limit values (mg/Nm^3).

			MWth									
Poll	**Date**	**Type**	**50**	**100**	**150**	**200**	**250**	**300**	**350**	**400**	**450**	**500**
SO_2	88	S	2000	2000	1800	1600	1400	1200	1000	800	600	400
	98	S	850	850	688	525	363	200	200	200	200	200
	88	L	1700	1700	1538	1375	1213	1050	888	725	563	400
	98	L	850	850	688	525	363	200	200	200	200	200
	88	G	35	35	35	35	35	35	35	35	35	35
	98	G	35	35	35	35	35	35	35	35	35	35
	88	B										
	98	B	200	200	200	200	200	200	200	200	200	200
NO_x	88	S	650	650	650	650	650	650	650	650	650	650
	98	S	400	400	300	300	300	300	200	200	200	200
	88	L	450	450	450	450	450	450	450	450	450	450
	98	L	400	400	300	300	300	300	200	200	200	200
	88	G	350	350	350	350	350	350	350	350	350	350
	98	G	150	150	150	150	150	150	100	100	100	100
	88	B										
	98	B	350	350	300	300	300	300	300	300	300	300

Note: the ELVs for gas are for gas turbines using natural gas, the limit value in most cases being 50 mg NO_x/m^3.

Concentrations of SO_2 and NO_x have been estimated for the best plants. Note that the estimation relies on:

- Estimates of thermal efficiency and fuel input (MWth).
- Information about combustion plant design. The plant may have different heat engine cycles (e.g. steam cycle, combined cycle gas turbine) and variant design details such as fuel/air ratios which affect concentrations.

- Knowledge of fuel inputs. Many plants are capable of using more than one fuel type.

Data are not available for all of these parameters for all plant. Therefore generalisations and assumptions have had to be used in some cases.

Table 14 shows the estimates of emission concentrations for the best plants, and compares them with EU ELVs. This listing does not exactly correspond with Table 5 because aggregation by plant was carried out for that list. Note also that the sorting by increasing pollution per output (as in Table 5) does not necessarily produce the same results as ordering by pollution exhaust concentrations.

Table 14. Emission concentrations of best plants.

	Sulphur dioxide					Nitrogen oxides				
	mg SO_2/Nm^3					mg NO_2/Nm^3				
Name	**ELV88**	**ELV98**	**Plant**	**%ELV88**	**%ELV98**	**ELV88**	**ELV98**	**Plant**	**%ELV88**	**%ELV98**
Derwent	35	35	0	0%	0%	350	100	121	34%	121%
Auto	35	35	0	0%	0%	350	100	121	34%	121%
Västerås	400	200	42	10%	21%	650	200	104	16%	52%
Riedersbach	400	200	57	14%	28%	650	200	112	17%	56%
23 GCC PLANT	35	35	0	0%	0%	350	100	121	34%	121%
Kiel	400	200	76	19%	38%	650	200	143	22%	71%
Duernrohr	400	200	100	25%	50%	650	200	134	21%	67%
22 GAS PLANT	35	35	0	0%	0%	350	150	121	34%	80%
Gelderland	400	200	137	34%	69%	650	200	130	20%	65%
88 GAS AND GAS/OIL PLANT	35	35	0	0%	0%	350	150	121	34%	80%
Muenchen	400	200	17	4%	9%	650	200	260	40%	130%
Mellach	400	200	137	34%	68%	650	200	182	28%	91%
Tiefstack	400	200	72	18%	36%	650	200	250	38%	125%
Staudinger	400	200	126	31%	63%	650	200	192	29%	96%
Duernrohr	400	200	120	30%	60%	650	200	205	32%	102%
Hafen	1600	525	93	6%	18%	650	300	220	34%	73%
Schwandorf	400	200	108	27%	54%	650	200	211	32%	105%
Mannheim	400	200	144	36%	72%	650	200	188	29%	94%
Gersteinwerk	400	200	232	58%	116%	650	200	110	17%	55%
Aschaffenburg	400	200	123	31%	62%	650	200	209	32%	105%
Rostock	400	200	95	24%	48%	650	200	260	40%	130%
Offleben	400	200	232	58%	116%	650	200	123	19%	61%
Scholven	400	200	185	46%	92%	650	200	185	28%	92%
Heilbronn	400	200	171	43%	86%	650	200	199	31%	100%
Neckar	400	200	205	51%	102%	650	200	176	27%	88%
Cuno-Herdecke	800	200	170	21%	85%	650	200	224	34%	112%
Wedel	400	200	232	58%	116%	650	200	182	28%	91%
Sandreuth	1600	525	135	8%	26%	650	300	52	8%	17%
Hannover	400	200	275	69%	137%	650	200	182	28%	91%
Voelklingen	400	200	288	72%	144%	650	200	182	28%	91%

Table 14. Emission concentrations of best plants (continued).

	Sulphur dioxide					Nitrogen oxides				
	mg SO_2/Nm^3					mg NO_2/Nm^3				
Name	**ELV88**	**ELV98**	**Plant**	**%ELV88**	**%ELV98**	**ELV88**	**ELV98**	**Plant**	**%ELV88**	**%ELV98**
Mainz	400	200	246	61%	123%	650	200	207	32%	103%
Martinlaakso	1400	362.5	42	3%	12%	650	300	428	66%	143%
Zolling-Leiningerwerk	400	200	204	51%	102%	650	200	273	42%	136%
Franken	400	200	166	42%	83%	650	200	322	50%	161%
Frankfurt	800	200	198	25%	99%	650	200	331	51%	165%
Veltheim	400	200	80	20%	40%	650	200	139	21%	70%
Herne	400	200	192	48%	96%	650	200	411	63%	205%
Uppsala	400	200	116	29%	58%	650	200	488	75%	244%
Knepper	400	200	129	32%	64%	650	200	121	19%	60%
Voerde	400	200	91	23%	46%	650	200	182	28%	91%
Arzberg	400	200	72	18%	36%	650	200	189	29%	94%
Wilhelmshaven	400	200	154	38%	77%	650	200	130	20%	65%
Farge	400	200	135	34%	67%	650	200	130	20%	65%
Reuter	400	200	127	32%	64%	650	200	182	28%	91%
Chemnitz	600	200	194	32%	97%	650	200	529	81%	265%
Västhamnsverket	1400	362.5	120	9%	33%	650	300	634	98%	211%
Suomenoja	1200	200	288	24%	144%	650	300	513	79%	171%
Walsum	400	200	492	123%	246%	650	200	305	47%	152%
Werdohl-Elverlingsen	400	200	134	34%	67%	650	200	198	30%	99%
Rudow	400	200	83	21%	42%	650	200	225	35%	113%
Voitsberg	400	200	90	23%	45%	650	200	254	39%	127%
Reuter	400	200	128	32%	64%	650	200	182	28%	91%
Walheim	400	200	89	22%	45%	650	200	231	36%	116%
Heyden	400	200	137	34%	68%	650	200	227	35%	114%
Shamrock	600	200	121	20%	61%	650	200	182	28%	91%
Buschhaus	400	200	247	62%	124%	650	200	614	95%	307%
West	400	200	126	32%	63%	650	200	225	35%	113%
Datteln	400	200	117	29%	58%	650	200	230	35%	115%
Westerholt	400	200	165	41%	82%	650	200	171	26%	85%
Boxberg	400	200	303	76%	151%	650	200	113	17%	57%
Munsdorf	600	200	298	50%	149%	650	200	614	95%	307%
Bexbach	400	200	196	49%	98%	650	200	209	32%	105%
Duisburg	400	200	216	54%	108%	650	200	169	26%	84%
Oberhavel	400	200	67	17%	34%	650	200	322	50%	161%
Rheinhafen	400	200	262	65%	131%	650	200	186	29%	93%
Hemweg	400	200	186	46%	93%	650	200	909	140%	454%
Peterhead	35	35	177	507%	507%	350	100	355	101%	355%
West	400	200	285	71%	143%	650	200	182	28%	91%
Luenen	400	200	138	35%	69%	650	200	293	45%	146%
Hanasaari	400	200	262	65%	131%	650	200	876	135%	438%

Table 14. Emission concentrations of best plants (continued).

	Sulphur dioxide					Nitrogen oxides				
	mg SO_2/Nm^3					mg NO_2/Nm^3				
Name	**ELV88**	**ELV98**	**Plant**	**%ELV88**	**%ELV98**	**ELV88**	**ELV98**	**Plant**	**%ELV88**	**%ELV98**
Kymijaervi	400	200	577	144%	288%	650	200	602	93%	301%
Westfalen	400	200	229	57%	115%	650	200	225	35%	113%
Abyverket	1600	525	855	53%	163%	650	300	325	50%	108%
Voelklingen	400	200	285	71%	143%	650	200	909	140%	454%
Weiher	400	200	324	81%	162%	650	200	169	26%	84%
Salmisaari	400	200	326	81%	163%	650	200	909	140%	454%
Hafen	1800	687.5	230	13%	33%	650	300	260	40%	87%
Grain	400	200	650	162%	325%	450	200	104	23%	52%
Jänschwalde	400	200	198	49%	99%	650	200	374	58%	187%
Timelkam	1400	362.5	81	6%	22%	650	300	1249	192%	416%
Neumuenster	1200	200	118	10%	59%	650	300	1281	197%	427%
Rauxel	400	200	232	58%	116%	650	200	320	49%	160%
Zeltweg	600	200	82	14%	41%	650	200	454	70%	227%
Mannheim	400	200	169	42%	85%	450	200	514	114%	257%
Vartan	400	200	169	42%	85%	450	200	514	114%	257%
Vaskiluoto	400	200	181	45%	90%	650	200	1290	199%	645%
Frimmersdorf	400	200	295	74%	147%	650	200	263	41%	132%
Toppilan	400	200	312	78%	156%	650	200	1243	191%	622%
Mussalo	1200	200	894	74%	447%	650	300	610	94%	203%
Fenne	400	200	279	70%	140%	650	200	322	50%	161%
Weiher	400	200	334	83%	167%	650	200	274	42%	137%
Seinaejoki	800	200	380	48%	190%	650	200	1298	200%	649%
Afferde	1600	525	1568	98%	299%	650	300	106	16%	35%
Amer	400	200	186	46%	93%	650	200	532	82%	266%
Uppsala	400	200	1690	423%	845%	450	200	514	114%	257%
Tahkoluoto	400	200	122	30%	61%	650	200	584	90%	292%
Fawley	400	200	892	223%	446%	450	200	114	25%	57%
Schkopau	400	200	945	236%	473%	650	200	878	135%	439%
Haapaniemi	1200	200	607	51%	303%	650	300	1220	188%	407%
Meri	400	200	349	87%	174%	650	200	454	70%	227%
Kilroot	400	200	1265	316%	632%	650	200	586	90%	293%
Ratcliffe	400	200	306	76%	153%	650	200	448	69%	224%
Fusina	400	200	518	130%	259%	650	200	267	41%	134%
Bielefeld	1400	362.5	610	44%	168%	650	300	1279	197%	426%
Flensburg	400	200	1007	252%	503%	650	200	1047	161%	524%
Merkenich	1400	362.5	809	58%	223%	650	300	1298	200%	433%
Värtaverket	400	200	1283	321%	641%	650	200	883	136%	441%
Kristiinan	400	200	354	89%	177%	650	200	645	99%	323%

APPENDIX C

OPERATORS AND UTILITIES

Table 15 gives a list of electricity utilities and unique acronyms used in tables. To correctly list all operators' names has not been possible in this study: accordingly the acronyms are not necessarily those used by the utilities, and some utilities appear more than once.

Table 15. Electricity utilities and acronyms.

Austria (AUT)	
EVN	Energie- Versorgung Niederoesterreich AG
LEFUV	Linzer Elektrizitaets- Fernwaerme- und Verkehrsbetriebe AG
ODK	Oesterreichische Draukraftwerke AG
OKA	Oberoesterreichische Kraftwerke AG
SAFE	Salzburger AG Fuer Energiewirtschaft
STEWAG	Steirische Wasserkraft und Elektrizitaets AG
VKG	Verbundkraft Elektrizitaetswerke GmbH
Belgium (BEL)	
EBES	EBES
Electrabel	Electrabel SA
Intercom	Intercom
SCK-CEN	SCK-CEN
SG	SPE GENT
SOCOLIE	SOCOLIE
UNERG	UNERG
Bulgaria (BGR)	
NEK	Natsionalna Elektricheska Kompania
SC	Svilosa Company
Vidachim	Vidachim
Bosnia-Herzegovina	
EPBiH	Elektroprivreda Bosne i Hercegovine
Switzerland (CHE)	
BC	Buendner Cement
BKW	BKW
CTDVS	Cent. Thermique se Vouvry SA
KKG-D	KKG-D
KKL	KKL
NOK	NOK
Czech Republic (CZE)	
CAS	Chemopetrol AS
CEZ	Czech Power Company
CEZ	Ceske Energeticke Zavody
CEZ-OKE	CEZ-OKE Elektr.J.Sverma(Ostr.)
CSAK	CS Armady (Karvina)
ECKA	Energeticke Centrum Kladno AS
EOA	Elektrarny Opatovice as
JCEB	JCE SP Teplarna Ceske Budejov.
JCES	JCE SP (Strakonice)
JCET	JCE, S.P., Teplarna (Tabor)
JESP	Jihoceske Elektr.SP (Mydlovary
MTA	Moravskoslezske teplarny a.s.
NRG	NRG Energy Inc
PKS	Palivovy Komb. S.P.
PSTA	Prvni severozapadni teplarenska as
PTA	Prazska teplarenska a.s.
SCTSPk	SCT SP Teplarna Komorany
SCTSPl	SCT SP Teplarna Liberec
SCTSPn	SCT SP T.Teplice (Nov.Sedlice)
SCTSPT	SCT SP Odstepny Zav.Tep.Trmice
TZKV	Teplarsky Zavod Karlovy Vary
Germany (DEU)	
AOA	Adam Opel AG
AVR	AVR
BA	Buna AG
BAG	Bayer AG
BASF	BASF AG
Bayern	Bayernwerk
Berlin	Berlin
BEWAG	Berliner Kraft- und Licht - AG
BKB	BKB
BWAG	Badenwerk AG
CWH-AG	CWH-AG
Dow	Dow Chemical GmbH
ELEKTROMARK	ELEKTROMARK
EMRG	EW Minden Ravensberg GmbH
EnBW	Energie-Baden Wuerttemberg AG
EOA	Energieversorgung Oberfranken AG
EOAG	Energieversorgung Offenbach
ESAG	Energieversorgung Sudsachen AG
ESOAG	Energieversorgung Sachsen Ost AG

Table 15. Electricity utilities and acronyms (Cont.).

ESPAG	Engergiewerke Schwarze SPump AG
EVO	EVO
EVSAG	Energie-Versorgung Schwaben AG
EWAG	Energie- und Wasserversorgung AG
EWAGN	EWAG Nuernberg
GEW Koln	Gas- Elektrizitaets- und Wasserwerke Köln AG
GKN	GKN
GKW	Gemeinsch-KW
GKWF	GKW Franken AG
GKWM	GKW Mannheim
GKWMe	GKW Mehrum
GKWW	GKW Weser
GMKW	GMKW Kiel GmbH
GWG	Gemeinschaftskraftwerk Weser GmbH
HAG	Harpener AG
HEW	Hamburgische Electricitaets-Werke AG
HK	Henkel KGAA
HKG	HKG
HPB	Hartz Paper Bavaria
HuAG	Huels AG
IAAG	Isar-Amperwerke AG
IBW	Ilse-Bayern-Werk Gmbh
KBG	KBG
KGB	KGB
KKB	KKB
KKG	KKG
KKI	KKI
KKK	KKK
KKP	KKP
KKS	KKS
KKU	KKU
KLE	KLE
KMA	KEW Mark AG
KMG	Kraftwerk Mehrum GmbH
KMW	Kraftwerk Mainz-Wiesbaden
KNG	KNG Kraftwerks- und Netzgesellschaft GmbH
KWG	Kraftwerk Wehrden GmbH
KWO	KWO
LAG	Leuna AG
MIBRAG	Mitteldeutsche Braunkohlenwerke AG
MKAG	Main-Kraftwerke AG
MKAGF	Mainkraftwerke AG Frankfurt
NWEAG	Neckarwerke Elektr.-vers.AG
OSEAG	Oder-Spree Energieversorgung AG
OTEV	Ostthueringer Energieversorgung AG
PEAG	PreussenElektra AG
PKG	Peissenberger Kraftw. Gmbh
PREAG	PREAG
RWE	RWE
RWP	Rheinisch-Westfalisc./Preussag
SAG	Saarbergwerke
SB	Stadtwerke Bielefeld
SBA	Stadtwerke Braunschweig AG
SBAG	Stadtwerke Bremen AG
SBG	Stadtwerke Braunschweig GmbH
SBK	SBK
SCAFPAG	SCA Fine Paper GmbH
SCAG	Stadtwerke Chemnitz AG
SCoAG	Stadtwerke Cottbus GmbH
SDAG	Stadtwerke Dusseldorf AG
SEAG	Stadtwerke Erlangen AG
SFAG	Stadtwerke Flensburg GmbH
SFrAG	Stadtwerke Frankfurt
SHAG	Stadtwerke Hannover AG
SKAG	Stadtwerke Karlsruhe
SMAG	Stadtwerke Muenchen
SMuAG	Stadtwerke Muenster
SNAG	Stadtwerke Neumuenster
SPAG	Stadtwerke Pforzheim
SSAG	Stadtwerke Saarbrucken
STEAG	STEAG
STWF	STW Frankfurt
SWAG	Stadtwerke Wuerzburg AG
SWuAG	Stadtwerke Wupperthal
TWS	TW Stuttgart
URBKAG	Union Rhein-braunk.kraftst.ag
VEAG	VEAG
VEW	Vereinigte Elektrizitaetswerke Westfalen AG
VEWD	VEW AG Dortmund
VKR	VEBA Kraftwerke Ruhr AG
VSE	VSE
VWK	VW Kraftwerk GmbH
Denmark (DNK)	
ELKRAFT	ELKRAFT
ELSAM	Nordjyllandsvaerket I/S ELSAM
ELSAM	Fynsvaerket I/S ELSAM
EW	Elektrizitatsw. Wesertal
RKV	Randers kommunale Vaerker RKV
SHA	Sonderjyllands Hojspaendingvaerk AN/S
Spain (ESP)	
ANV	ANV
CDT	CDT
CEDL	Cia Electrica de Langreo
CNA	CNA
CSev	C Sevillana
CTDNS	Centrales Termica del Norte SA
Elcogas	Elcogas SA
ELSAM	ELSAM

ENCS	Empresa nacional Calvo Soltelo
ENDESA	Empresa Nacional de Electricidad SA
ENECO	Empresa Nacional Electrica de Cordoba SA
ENHER/FECSER	ENHER/FECSER
ENS	Empresa Nacional Siderurgica
ERZ	Empresa Ruinidas de Zaragoza SA
FECSA	FECSA
GESA	Gas y Electricidad
H Espanola	H Espanola
HDC	Hidroelectrica del Cantabrico SA
HIFRENSA	HIFRENSA
Iberdrola	Iberdrola S.A.
Iberduero	IBERDUERO
NUCLENOR	NUCLENOR
TB	Termica Besos
UEDC	Union Electrica De Canarias SA
UEFSA	UEFSA
UNESA	Union Electrica SA. H. Espanola
UTSA	Union Termica S.A.

Finland (FIN)

ESO	Espoon Saehkoe Oy
HE	Helsingin Energia
HKE	Helsingin Kaup. Energial.
IVO	Imatram Voima
KE	Kuopion Energia
KE	Kuopion Energialaitos
KH	Kotkan Hoyryvoima
LL	Lahden Lampovoima
LLO	Lahden Laempoevoima Oy
LV	Lansirannikon Voima
OKE	Oulun Energia
PVO	Pohjolan Voima
SH	Stadt Helsinki
TKS	Tampereen Kaup. Sahkol.
TVO	TVO
VE	Vantaan Energia
VS	Vantaan Sahkolaitos
VV	Vaskiluodon Voima
VVO	Vaskiluodon Voima Oy

France (FRA)

CDF	Charbonnages de France
EdF	Electricite de France
HDBDL	Houllieres du Basin de Lorraine
RP	Rhone-Progil
SENA	SENA
SIDE	Societe Industrielle pour le Developpement de l'Energie

United Kingdom (GBR)

AA	Alcan Aluminium
AES	AES Corporation
BE	British Energy
BNFL	British Nuclear Fuels Ltd
EG	Eastern Generation Ltd
Lakeland	Lakeland
NatPow	National Power plc
NIES	Northern Ireland Electricity Services
PowGen	PowerGen plc
RJB	RJB Mining
ScotHydro	Scottish Hydro
ScotPow	ScottishPower

Greece (GRC)

PPC	Public Power Corporation

Croatia (HRV)

HEP	Hrvatska Elektroprivreda
TE	TE

Hungary (HUN)

HEP	Hrvatska Elektroprivreda	
MVMR	Magyar Villamos Muvek Rt	
IRL	ESB Electricity Supply Board ESB	
ITA	ENEL	ENEL Spa
KAZ	EkibE	Ekibastuzenergo
MDA	MoldE	Moldenergo
KAZ	EkibE	Ekibastuzenergo

Netherlands (NLD)

EBA	EBA
EPON	Elektriciteits-Produktiemaatschappij Oost- en Noord-Nederland
EPZ	Elektriciteits-Produktiemaatschappij Zuid-Nederland nv
ESM	ESM
EZH	Electriciteitsbedrijf Zuid-Holland nv
NVE	NV Energieproduktiebedrijf UNA
NVGKN	NVGKN
PZEM	PZEM
UNA	UNA

Norway (NOR)

NHA	Norsk Hydro A/S

Poland (POL)

EB	Elektrocieplownia Bedzin
EBl	Elektrownia Blachownia
EBS	Elektrocieplownia Bedzin SA
ECS	Elektrocieplownia Chorzow SA
EGS	Elektrocieplownia Gorzow SA
EH	Elektrownia Halemba
EI	Eurogas Inc
EITK	Elektrownia im T Kosciuszki SA
EJ	Elektrownia Jaworzno III
EK	Elektrownia Kozienice SA
EL	Elektrownia Lagiska
EO	Elektrownia Opole
ER	Elektrownia Rybnik
ES	Elektrownia Siersza

Table 15. Electricity utilities and acronyms (Cont.).

ESk	Elektrownia Skawina
ESW	Elektrownia Stalowa Wola
ET	Elektrownia Turow
EW	Elektrocieplowni Warzawskie PP
EZ	Elektrocieplowni Zabrze
EZE	Elbaskie Zaklady Energetyczne SA
GFA	Teplarsky Zavod Karlovy Vary
GSF	Gostyn Sugar Factory
LHM	Legnica Huta Miedzi
PAK	Zespol Elektrowni PAK SA
ZEB	Zespol Elektrocieplowni Bialystok
ZEBB	Zespol Elektrocieplowni Bielsko-Biala
ZEBSA	Zespol Elektrocieplowni Bydgoszcz SA
ZEDO	Zespol Elektrowni Dolna Odra
ZEE	Zaklad Energetyczny Elblag
ZEG	Zespol Elektrocieplowni Gdansk
ZEGE	Zaklad Energetyczny Gorzow Elektrocieplownia
ZEGZ	Zespol Elektrowni Gornoslaskich ‘Zachod’
ZEJ	Zespol Elektrowni Jaworzno
ZEK	Zespol Elektrocieplowni Krakow
ZEKo	Zespol Elektrowni Kozienice
ZEL	Zespol Elektrocieplowni Lodz
ZEM	Zespol Elektrocieplowni Miechowice
ZEO	Zaklad Energetyczny Opole
ZEOs	Zespol Elektrowni Ostroleka
ZEP	Zespol Elektrocieplowni Poznan
ZEW	Zespol Elektrocieplowni Warzawa
ZEWr	Zespol Elektrocieplowni Wroclaw
ZEWS	Zespol Elektrocieplowni Wybrzeze SA
ZEZ	Zaklad Energetyczny Zamosc
Portugal (PRT)	
EDP	Electricidade de Portugal S.A
PAK	Zespol Elektrowni PAK
Romania (ROM)	
RENEL	Romanian Electricity Authority
Russia (RUS)	
AkheE	Akhenergo
AltaE	Altaienergo
AmurE	Amurenergo
ArkeE	Arkenergo
ArkhE	Arkhenergo
BarnE	Barnaulenergo
BashE	Bashkirenergo
BuryE	Buryatenergo
ChelE	Chelyabenergo
ChitE	Chitaenergo
DaleE	Dalenergo
IrkuE	Irkustskenergo
IvanE	Ivanenergo
KhabE	Khabarovsenergo
KhakE	Khakassenergo
KiroE	Kirovenergo
KoleE	Kolenergo
KomiE	Komienergo
KrasE	Krasnoyarskenergo
KuzbE	Kuzbassenergo
LeneE	Lenenergo
MagaE	Magadanenergo
MinE	MinEnergo
MosE	Mosenergo
NovoE	Novosibirskenergo
OmskE	Omskenergo
OrenE	Orenburgenergo
OrskE	Orskenergo
RostE	Rostovenergo
RyazE	Ryazanenergo
SakhE	Sakhalinenergo
SibiE	Sibirenergo
SmolE	Smolenskenergo
SverE	Sverdlovenergo
TomsE	Tomskenergo
TulaE	Tulaenergo
TverE	Tverenergo
UralE	Uralenergo
VladE	Vladimirenergo
VoloE	Vologdaenergo
YakuE	Yakutenergo
Slovakia (SVK)	
CSV	Compressor Station V.Zlievce
EV	Elektraren Vojany
EZ	ENO Z.Kostolany
KS	Kotolna Svidnik
KSV	Kotolna Spisska V.Ves
KT	Kotolna Trebisov
SEP	Slovensky Energeticky Podnik
SlovE	Slovenske Elektrarne as
TP	TP
Slovenia (SVN)	
ELES	ELES
Sweden (SWE)	
ABA	AB Aroskraft
AK	ÄAngelholms Kommun
BK	Borås Kommun
BKAB	Bråvalla Kraft AB
DE	Drefvikens Energi
DO	DH only
GEAB	Göteborgs Energi AB
HEAB	Helsingborg Energi AB

Table 15. Electricity utilities and acronyms (Cont.).

HK	Halmstads Kommun
JE	Jönköpings Energiverk
KAB	KAB
KaEV	Kalmar Energiverk
KE	Katrineholm Energiverk
KK	Karlskoga Kommun
KKAB	Karlshamns Kraftverksgrupp AB
MaI	Malmö Industriverk
MoI	Mölndals Energiverk
NE	Norrköpings Energiverk
NKV	Nyköpings Kommun Värmeverket
OEVAB	Örebro Energi Värme AB
OKG	OKG
OE	Örebro Energi
SE	Sandvikens Energiverk
SEAB	Stockholm Energi AB
SoE	Södertälje Energiverk
SSPB	SSPB
SV	SV
TVIL	Tekniska Verken I Linköping
UEAB	Uppsala Energi AB
UMEAE	Umeå Energiverk
VE	Växjö Energiverk
VSKAB	Västerås Stads Kraftvärmeverk AB

Turkey (TUR)	
Etibank	Etibank
KOCH	KOC Holding
TEK	Turkiye Elektrik Kurumu
Ukraine (UKR)	
DnepE	Dnepenergo
DonbE	Donbassenergo
KharE	Kharkovenergo
KiyeE	Kiyevenergo
LvovE	Lvovenergo
MOPAE	Ministry of Power and Electrification Ukraine
TEK	Turkiye Elektrik Kurumu
VinnE	Vinnitsenergo
Yugoslavia (YUG)	
EL-TO	EL-TO
EPCG	Elektroprivreda Crne Gore
EPK	EPK
ES	Elektroprivreda Srbije ES
KTE	KTE
PTE	PTE
TE -TO	TE -TO

AIR POLLUTION AND CLIMATE SERIES

THE WORST ...

It is well known that a great part of the emissions of acidifying substances comes from a relatively small number of point sources, primarily coal-fired power stations. In this study it is estimated that the hundred largest ones alone emit more than eight million tons sulphur dioxide, which is about 40 per cent of the total in 1997. Of these hundred largest sulphur emitters, eighty-three are coal-fired power stations.

... AND THE BEST

When ranking the power stations by increasing pollution, it is shown that a large number of plants in operation have emission levels that are much lower than the limit values proposed by the Commission for new plants, i.e. plants that are to come into operation after 2003.

THE WORST AND THE BEST

has been commissioned by the Swedish NGO Secretariat on Acid Rain as a contribution to the debate on the revision of the EU directive on emissions of air pollutants from large combustion plants.

The Swedish NGO Secretariat on Acid Rain

The essential aim of the Swedish NGO Secretariat on Acid Rain is to promote awareness of the problems associated with air pollution, and thus, in part as a result of 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 four to five times a year and is distributed free of charge.
- 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 Convention on Long Range Transboundary Air Pollution.
- Acting as an observer at the proceedings involving international agreements for reducing the emissions of greenhouse gases.

The work of the secretariat is largely directed on the one hand towards eastern Europe, especially Poland, the Baltic States, Russia, and the Czech Republic, and on the other towards the European Union and its member countries. By emitting large amounts of sulphur and nitrogen compounds, 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 run by local environmentalist organizations.

To date, four European conferences on strategy for environmental NGOs have been arranged by the secretariat, where common objectives and cooperative projects were developed. An important outcome has also been the agreement on the demands, based on scientific data concerning critical loads.