EN07 Energy-related particulate matter emissions

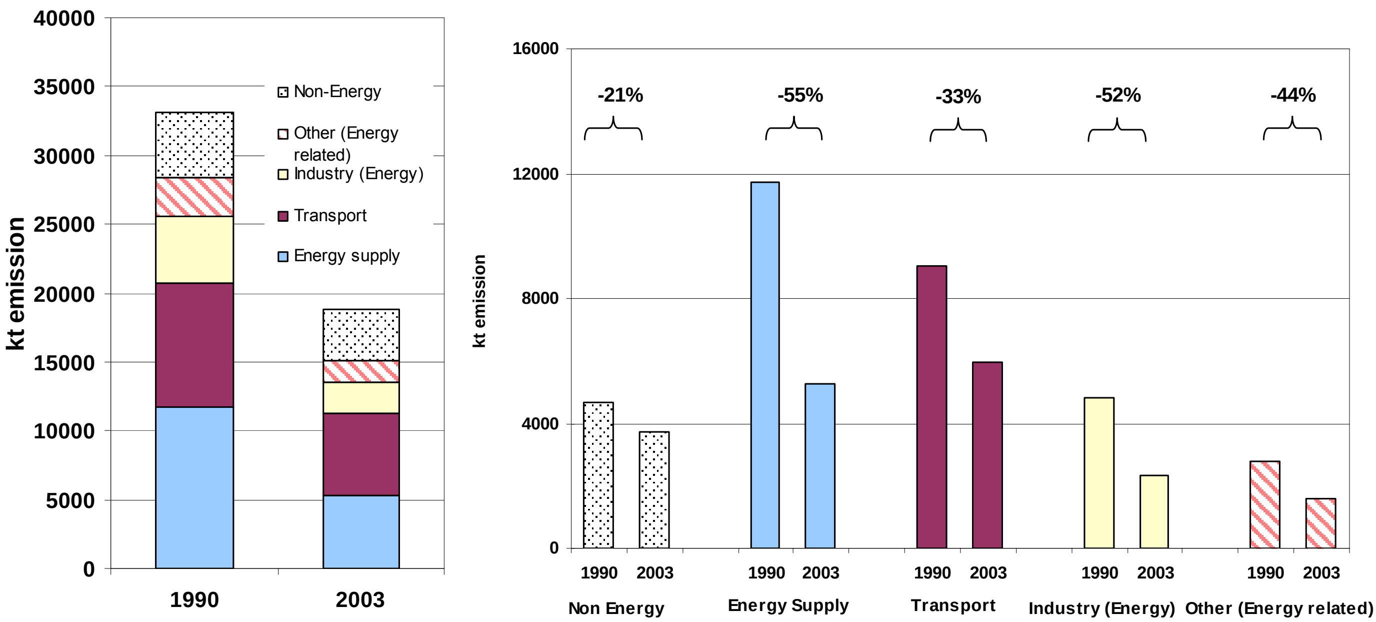
Key message

Reduced emissions of sulphur dioxide, nitrogen oxides and primary PM_{10} particulate matter from power plants and road transport helped to achieve a 47 % reduction in energy-related particle emissions in EU-25 during the period 1990-2003. The most important reductions were achieved in energy supply and industry as a result of the use of lower sulphur content fuels and fuel switching from coal and oil to natural gas.

Rationale

Energy-related emissions of primary PM_{10} (particulate matter with a diameter of 10µm or less, emitted directly into the atmosphere), and secondary PM_{10} precursors (the fraction of NO_x, SO_2, and NH_3 emissions which, as a result of photo-chemical reactions in the atmosphere, transform into particulate matter with a diameter of 10 µm or less), contribute to elevated levels of fine particles in the atmosphere. The inhalation of such particles has harmful effects on human health and may increase the frequency and severity of a number of respiratory problems, which may increase the risk of premature death.

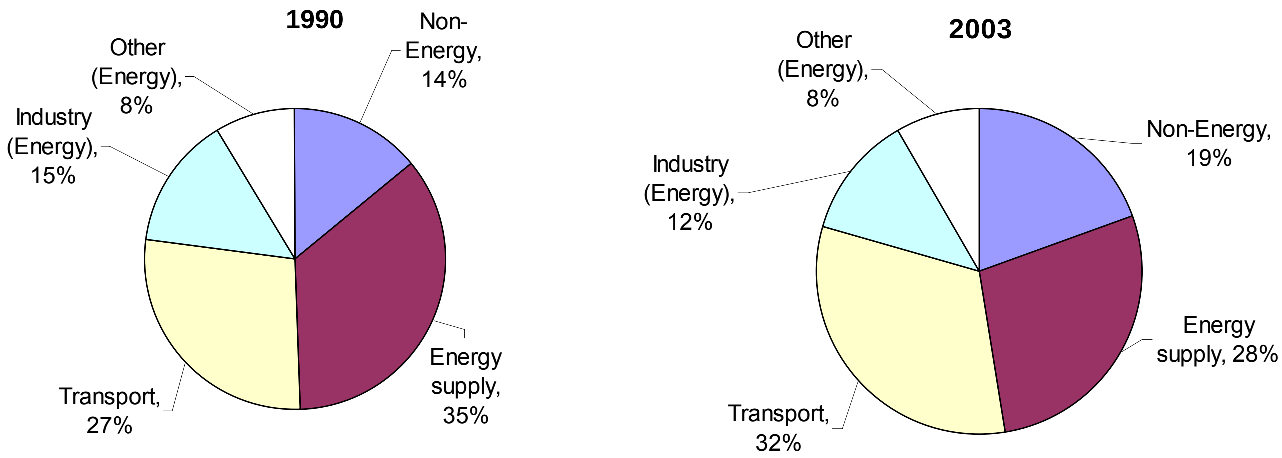
Fig. 1: Total and sectoral energy-related emissions of primary and secondary PM_{10} particulate matter emissions, EU-25 (weighted using particle formation factors)



Notes: The graph above shows the emissions of primary PM10 particles (particulate matter with a diameter of 10µm or less, emitted directly into the atmosphere) and secondary particulate-forming pollutants (the fraction of sulphur dioxide, SO_2, nitrogen oxides NOx and ammonia NH3 which, as a result of photo-chemical reactions in the atmosphere, transform into particulate matter with a diameter of 10µm or less). Emissions of the secondary particulate precursor species are weighted by a particle formation factor prior to aggregation: primary PM_{10} = 1, SO_2 = 0.54, NO_x = 0.88, and w(NH_3) = 0.64 (de Leeuw, 2002). Particulate matter arising from NH_3 is included in the totals under Non-Energy related emissions. Values of PM_{10} reported by Portugal appear to be reported using incorrect units, being 1000 times lower in magnitude than would be expected and so have been adjusted.

Source: ETC-ACC 2005.

Fig. 2: Sectoral shares of particulate matter formation pollutants (energy and non-energy components) in total emissions, EU-25



Source: ETC-ACC 2005.

1. Indicator assessment

Energy-related particulate matter emissions (both primary and secondary PM_{10}) in the EU-25 have fallen by 47 % between 1990 and 2003. Of energy-related particulate matter emissions in 2003, the most significant contributing pollutants were NO_x and SO_2 (see EN06 for a detailed description of trends of NO_x and SO_2). The percentage decrease for primary PM_{10} emissions was significantly lower than that observed for the two other pollutants which is largely due to a large increase in reported emissions by Poland for the energy industries sector. Nevertheless, despite this reduction of primary PM_{10}, energy-related sectors were still responsible for 80 % of total particulate matter emissions to the atmosphere in 2003.

The majority of the reduction in emissions of energy-related particulate matter pollutants between 1990 and 2003 came from the energy supply sector, although the other sectors also decreased emissions significantly during this period (Fig 1). Overall, the reduction in emissions of energy-related particulate matter pollutants was mainly achieved through a combination of the use of lower sulphur content fuels, fuel switching from coal and oil to natural gas, the deployment of emission abatement technologies in the energy supply (see EN09 for further details about emissions of SO_2 and NO_X from public electricity production) and industry sectors, and an increased market penetration of catalytic converters for road vehicles.

Emissions from transport decreased by 33 % between 1990 and 2003, contributing significantly to the overall reduction of particulate matter emissions. Emissions of primary PM_{10} and secondary PM_{10} precursors are expected to further decrease significantly between 2003 and 2010 (despite an increasing popularity of diesel vehicles in many countries), as improved vehicle engine technologies are adopted and stationary fuel combustion emissions are controlled through abatement measures (including particulate traps) or use of low sulphur fuels such as natural gas. It is noted however, that not all improved engine technologies lead to lower emissions of particulate matter e.g. gasoline direct injection (GDI) engines while offering certain benefits such as improved fuel economy, produce higher particulate matter emissions (g/km) than a normal gasoline motor.

Despite the reductions in emissions already achieved, it is expected that in the near future concentrations of PM10 in most of the urban areas in the EEA region are expected to remain well above the short-term limit air quality values (EEA 2005). Substantial further reductions in all sectors are therefore needed to reach the limit values set in the EU first Daughter Directive to the Framework Directive on Ambient Air Quality. Additional measures to reduce the sulphur content of diesel and petrol fuels have been decided upon (Directive 2003/17/EC), which include the availability of the sulphur-free (<10 ppm sulphur or 'zero sulphur') fuel from 2005 in Member States, and complete transition to sulphur-free fuel by 2009. These measures should reduce emissions of NO_x and SO_2, as well as primary PM_{10}, from road vehicles in the future.

Emissions of SO_2 and NO_x from shipping in European waters are expected to increase by 2010 with an associated increase in primary and secondary PM_{10} precursors (European Commission, 2005).

2. Indicator rationale

2.1 Environmental context

Energy-related emissions of primary PM_{10} (particulate matter with a diameter of 10µm or less, emitted directly into the atmosphere), and secondary PM_{10} precursors (the fraction of NO_x, SO_2 and NH_3 emissions which, as a result of photo-chemical reactions in the atmosphere, transform into particulate matter with a diameter of 10µm or less), contribute to elevated levels of fine particles in the atmosphere. The inhalation of such particles has harmful effects on human health and may increase the frequency and severity of a number of respiratory problems, which may increase the risk of premature death.

Emission data for primary PM_{10} is not as robust as that for other pollutants and is subject to high uncertainty. The factors used in the estimation of secondary PM_{10} emissions are based on assumptions about the deposition and reactions of the precursor pollutants (see metadata section for further details).

2.2 Policy context

There are no direct *emission* limits or targets for primary PM_{10} within the European Union, although there are limits on emissions of the precursor pollutants NO_x, SO_2 and NH_3. Limit values for the *concentration* of PM_{10} are set under EU Directive 99/30/EC relating to ambient air quality assessment and management (European Commission 1999).

Several EU-wide emissions limits and targets exist for the reduction of SO_2, NO_x and NH_3, including the National Emissions Ceiling (NEC) Directive (2001/81/EC) and the UNECE CLRTAP Gothenburg Protocol under UNECE CLRTAP (UNECE 1999). These are discussed further in factsheet EN06.

Levels of fine particulate matter and precursor emissions are controlled in the European Union by 3 main types of regulation:

- Air quality standards.
- Emission standards for specific (mobile or stationary) sources.
- National emission ceilings and transboundary air pollution standards for emission precursors.

Limit values for the *concentration* of PM_{10} are set under EU Directive 99/30/EC relating to ambient air quality assessment and management .

Fig. 3: Energy-related emissions of (primary and secondary) particulate matter 1990-2003 (kt)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	% Change 1990-2003
Austria	242	249	232	227	217	214	231	217	225	214	216	226	230	240	-1%
Belgium	508	480	488	479	445	461	430	413	414	378	389	357	355	354	-30%
Bulgaria	1332	1083	776	945	938	973	944	892	838	654	672	650	674	685	-49%
Cyprus	42	34	39	42	41	40	44	45	47	48	49	43	43	41	-4%
Czech Republic	1662	1594	1448	1277	1083	987	927	786	638	525	529	460	403	453	-73%
Denmark	360	435	367	349	348	327	379	300	268	243	212	207	205	216	-40%
Estonia	235	227	175	155	156	140	146	143	140	131	121	116	117	118	-50%
Finland	395	354	323	316	313	284	304	298	290	287	282	276	263	278	-30%
France	2553	2715	2565	2378	2276	2193	2166	2002	1995	1860	1724	1646	1553	1511	-41%
Germany	5330	4423	3891	3600	3207	2796	2404	2159	1998	1901	1772	1715	1641	1584	-70%
Greece	590	612	614	608	593	601	600	599	621	622	582	609	605	605	3%
Hungary	804	724	672	625	620	604	584	577	541	537	470	419	392	389	-52%
Iceland	35	36	37	38	40	40	33	26	27	27	27	27	27	27	-22%
Ireland	217	214	219	204	209	202	199	208	216	203	195	201	176	155	-28%
Italy	2765	2742	2716	2559	2452	2392	2303	2187	2019	1886	1738	1693	1567	1567	-43%
Latvia	118	97	81	81	83	66	71	62	57	52	42	43	41	41	-65%
Liechtenstein	1	1	0	0	0	0	0	0	0	0	0	0	0	0	-38%
Lithuania	256	269	160	135	130	109	110	94	106	88	67	74	66	66	-74%
Luxembourg	31	32	32	33	30	26	26	21	19	18	18	18	18	18	-41%
Malta	1	1	1	1	1	1	1	1	1	1	1	1	1	1	28%
Netherlands	613	610	596	573	548	507	506	469	461	461	402	388	376	379	-38%
Norway	250	237	235	246	246	244	256	259	257	258	243	242	237	244	-3%
Poland	3167	2911	2757	2696	2620	2457	2483	2350	2098	1971	1755	2053	2053	2053	-35%
Portugal	435	444	497	459	446	471	431	446	481	489	471	454	458	458	5%

Romania	1128	933	788	745	737	731	725	719	714	578	628	739	739	739	-34%
Slovakia	517	446	400	364	309	318	274	254	247	232	200	202	184	176	-66%
Slovenia	169	155	159	162	161	133	130	133	130	115	110	95	97	90	-47%
Spain	2361	2403	2415	2324	2320	2260	2106	2244	2175	2243	2203	2166	2283	2171	-8%
Sweden	399	388	378	354	351	333	319	297	287	267	252	249	245	249	-38%
Switzerland	160	177	164	150	138	125	131	124	106	96	95	89	85	90	-44%
Turkey	1422	1468	1474	1515	1622	1641	1789	1826	1878	1953	1941	1909	1849	1790	26%
United Kingdom	4675	4467	4349	4007	3696	3387	3137	2784	2693	2382	2284	2171	2026	1996	-57%
EU-10	6972	6458	5891	5538	5203	4855	4771	4447	4005	3699	3344	3507	3399	3428	-51%
EU-15	21475	20569	19684	18472	17449	16454	15539	14643	14163	13456	12741	12377	12000	11780	-45%
EU-25	28448	27027	25575	24009	22652	21309	20311	19090	18168	17155	16085	15883	15399	15208	-47%
EEA	32775	30961	29049	27648	26373	25064	24189	22937	21988	20722	19693	19542	19012	18783	-43%

Source: ETC-ACC 2005.

References

- de Leeuw, (2002), A set of emission indicators for long-range transboundary air pollution, Environmental Science & Policy, Volume 5, Issue 2, April 2002, Pages 135-145. (http://www.sciencedirect.com/science/article/B6VP6-44HYMJ7-1/1/d6e469ff7969874250c6d0f656a8c76b) (supported by the European Topic Centre on Air and Climate Change, under contract to the European Environment Agency);
- EEA (2005). Exceedance of air quality limit values in urban areas. Core Set of Indicators (CSI 004) - May 2005 Assessment.
- EMEP (2005a). Transboundary Acidification, Eutrophication and Ground Level Ozone in Europe in 2003. EMEP Status Report 2005. ISSN 0806-4520
- European Commission (2005), Thematic Strategy on Air Pollution COM(2005)466 final, European Commission, Brussels.

Meta data

Technical information

1. Data source: Officially reported national total and sectoral emissions to UNECE/EMEP (United Nations Economic Commission for Europe/Co-operative programme for monitoring and evaluation of the long range transmission of air pollutants in Europe) Convention on Long-range Transboundary Air Pollution (CLRTAP), 2004 data submission. Base data are available on the EMEP website (http://webdab.emep.int/). Where primary PM10 data was not available, (for countries Germany, Greece and Luxembourg) national primary PM10 emission totals and sector data have been obtained from the RAINS PM10 model using the BL_CLE_Apr04 scenario (http://www.iiasa.ac.at/web-apps/tap/RainsWeb/). Total energy consumption data from EUROSTAT http://europa.eu.int/comm/eurostat/ Emissions of primary particles and secondary particulate precursors is one of the European Environment Agency's core-set indicators. More information can be found at http://themes.eea.eu.int/IMS/CSI.

2. Description of data: Combination of primary PM_{10} data, and emissions of secondary PM_{10} precursors (SO_2 and NO_x and NH_3) weighted using aerosol formation factors (according to de Leeuw, 2002) NO_X = 0.88, SO_2 = 0.54 and NH_3 = 0.64. Gaps in reported data have been filled by ETC/ACC where necessary using simple interpolation techniques (see 6).

3. Geographical coverage: EU-25. Other analyses include data for EFTA 4 (Iceland, Liechtenstein, Switzerland and Norway) and Bulgaria, Romania, Croatia and Turkey. The EEA country grouping includes EU-25, EFTA4 and Bulgaria, Romania and Turkey.

4. Temporal coverage: 1990-2003

5. Methodology and frequency of data collection: Annual country data submissions to UNECE/CLRTAP/EMEP. Combination of emission measurements and emission estimates based on volume of activities and emission factors. Recommended methodologies for emission data collection are compiled in the Joint EMEP/CORINAIR Atmospheric Emission Inventory Guidebook 3rd edition EEA Copenhagen EEA (2001).

6. Methodology of data manipulation, including making 'early estimates': Emissions of secondary PM_{10} are estimated using aerosol 'formation factors' obtained from de Leeuw, 2002. Factors are NO_X = 0.88, SO_2 = 0.54 and NH_3 = 0.64. Results are in PM_{10} equivalents (ktonnes). ETC-ACC gap-filling methodology. To allow trend analysis, where countries have not reported data for one, or several years, data has been interpolated to derive annual emissions. If the reported data is missing either at the beginning or at the end of the time series period, the emission value has been considered to equal the first (or last) reported emission value. It is recognised that the use of gap-filling can potentially lead to artificial trends, but it is considered unavoidable if a comprehensive and comparable set of emissions data for European countries is required for policy analysis purposes. A list of the data used within this sheet which has been gap-filled is available from http://dataservice.eea.eu.int/dataservice/metadetails.asp?id=818
The energy supply sector includes public electricity and heat production, oil refining, production of solid fuels and fugitive emissions from fuels. The transport sector includes emissions from road and off-road sources (e.g. railways and vehicles used for agriculture and forestry). Industry (Energy) relates to emissions from combustion processes used in the manufacturing industry including boilers, gas

turbines and stationary engines. 'Other (energy-related)' covers energy use principally in the services and household sectors.
Values of PM10 reported by Portugal appear to be reported using incorrect units, being 1000 times lower in magnitude than would be expected. Thus, PM10 data for Portugal have been multiplied by 1000.

Quality information

7. Strengths and weaknesses (at data level): Strength: officially reported data following agreed procedures and Emission Inventory Guidebook (EEA 2001), e.g. regarding source sector split. Weakness: Primary PM_{10} data reported by countries remains uncertain in terms of quality for many countries (see reasons under point 8). In many cases the available reported data does not include all years and had to be interpolated. The incomplete reporting and resultant extrapolation may obscure some trends. The aerosol formation factors do not, as yet, have wide support or recognition.

8. Reliability, accuracy, robustness, uncertainty (at data level):

   The reported primary PM_{10} data is likely to be very uncertain. Much of the uncertainty in the overall reported PM_{10} emissions comes from uncertainties associated with emission factors. For many countries there is little country-specific data available from which PM_{10} emission factors can be determined. Emission factors in the literature can be very variable due to the differences that occur between sector processes both within and between different countries. For many countries a complete time series of PM_{10} data is not available from 1990, and so significant interpolation and extrapolation has had to be performed to obtain a complete time series of data. Similarly not all countries report emissions from every sector.
   In contrast, the uncertainties of sulphur dioxide emission estimates in Europe are relatively low, as the sulphur emitted comes from the fuel burnt and therefore can be accurately estimated. However, because of the need for interpolation to account for missing data the complete dataset used here will have higher uncertainty. EMEP has compared modelled (which include emission data as one of the model parameters) and measured concentrations throughout Europe (EMEP 2005a). From these studies the uncertainties associated with the modelled annual averages for a specific point in time have been estimated in the order of ±30 %. This is consistent with an inventory uncertainty of ±10 % (with additional uncertainties arising from the other model parameters, modelling methodologies, and the air quality measurement data etc).
   NO_x emission estimates in Europe are thought to have higher uncertainty than pollutants such as SO_2, as the NO_x emitted comes both from the fuel burnt and the combustion air and so cannot be estimated accurately from fuel nitrogen alone. EMEP has compared modelled and measured concentrations throughout Europe (EMEP 2005a). From these studies differences for individual monitoring stations of more than a factor of two have been found. This is consistent with an inventory of national annual emissions having an uncertainty of ±30% or greater (there are also uncertainties in the air quality measurements and especially the modelling).
   The trend is likely to be much more accurate than for individual absolute annual values; the annual values are not independent of each other. However it is not clear that all countries backdate changes to methodologies so early years may have been estimated on a different basis to later years.

9. Overall scoring (1 = no major problems, 3 = major reservations):
   - Relevance: 1
   - Accuracy: 2 (3 for primary PM_{10})
   - Comparability over time: 2
   - Comparability over space: 2