EN07 Energy-related particulate matter emissions

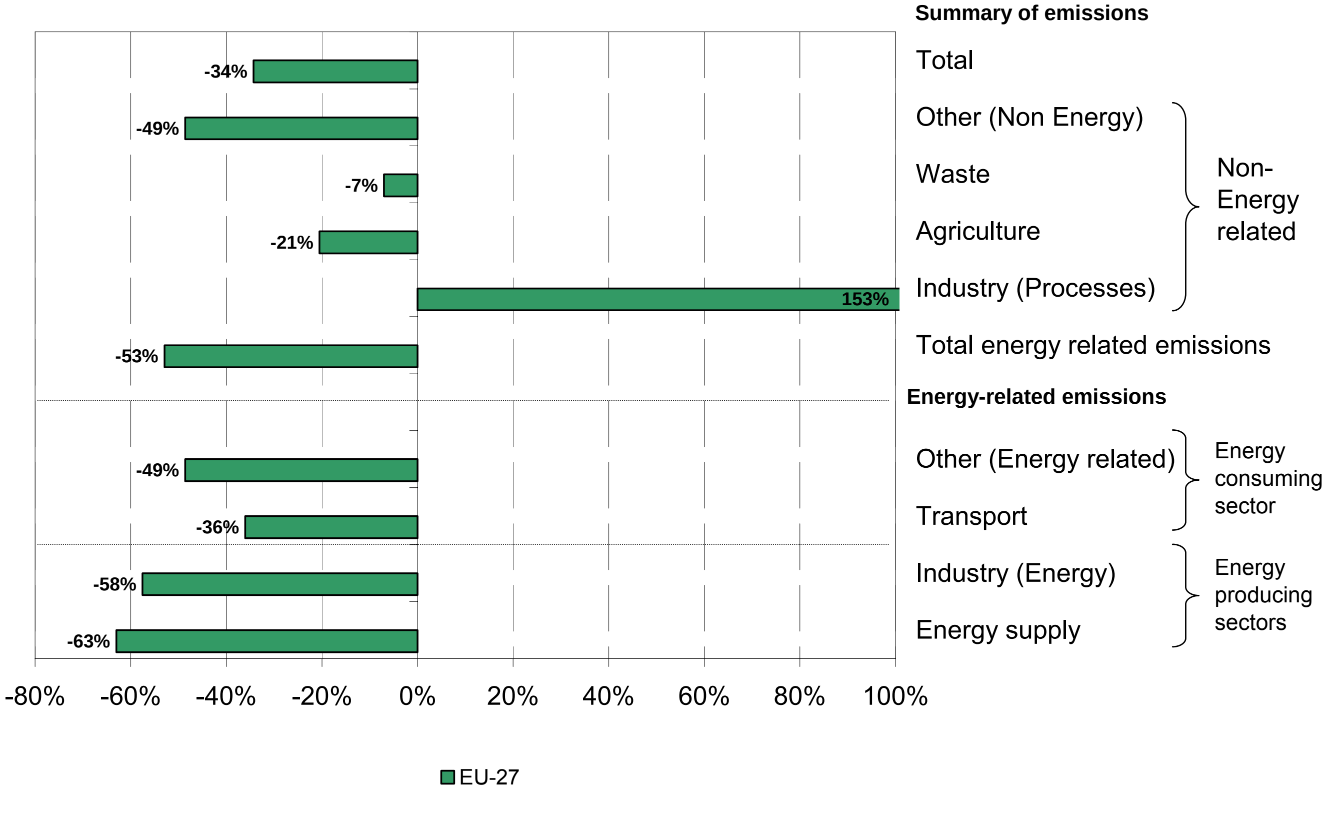
Key message

Reduced emissions of sulphur dioxide, nitrogen oxides and primary PM_{10} particulate matter from power plants and road transport helped to achieve a 53 % reduction in energy-related particle emissions in EU-27 between the period 1990-2005. The most important reductions were achieved in the energy supply and industry sectors as a result of using 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)[1], 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: Changes (%) in emissions of primary and secondary PM_{10} particulate matter emissions by source category, 1990-2005, EU-27 (weighted by tropospheric ozone formation potential)



Notes: The graph shows the emissions of primary PM_{10} particles (particulate matter with a diameter of 10 µm or less, emitted directly into the atmosphere) and secondary particulate-forming pollutants (the fraction of sulphur dioxide, SO_2, nitrogen oxides NO_x and ammonia NH_3 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

[1] PM_{10} definition: "PM10" shall mean particulate matter which passes through a size-selective inlet with a 50 % efficiency cut-off at 10 µm aerodynamic diameter (Air Quality Framework Directive, first Daughter Directive, article 2 (11) - (Council Directive 1999/30/EC of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air, Official Journal L 163 , 29/06/1999 P. 0041 - 0060):

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 (NH_3) = 0.64 (de Leeuw, 2002).

Source: EEA/ETC-ACC 2007.

Fig. 2a and 2b: Sectoral shares of primary particulate matter and secondary PM_{10} formation pollutants (energy and non-energy components) in total emissions, EU-27. Values within the segments indicate the level of particulate emissions (kt) emitted from each sector.

Fig: 2a Primary particulate matter

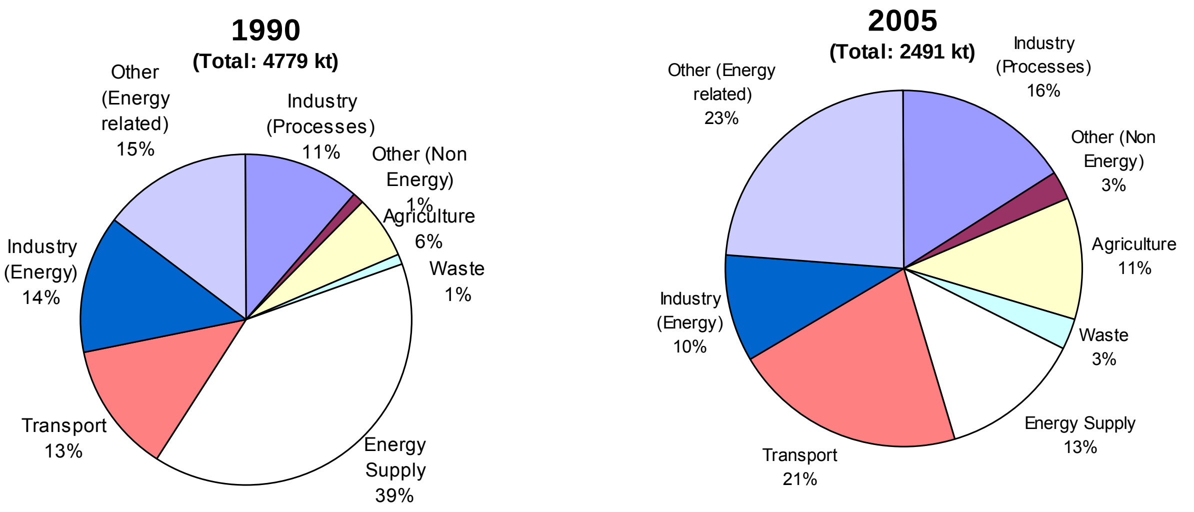
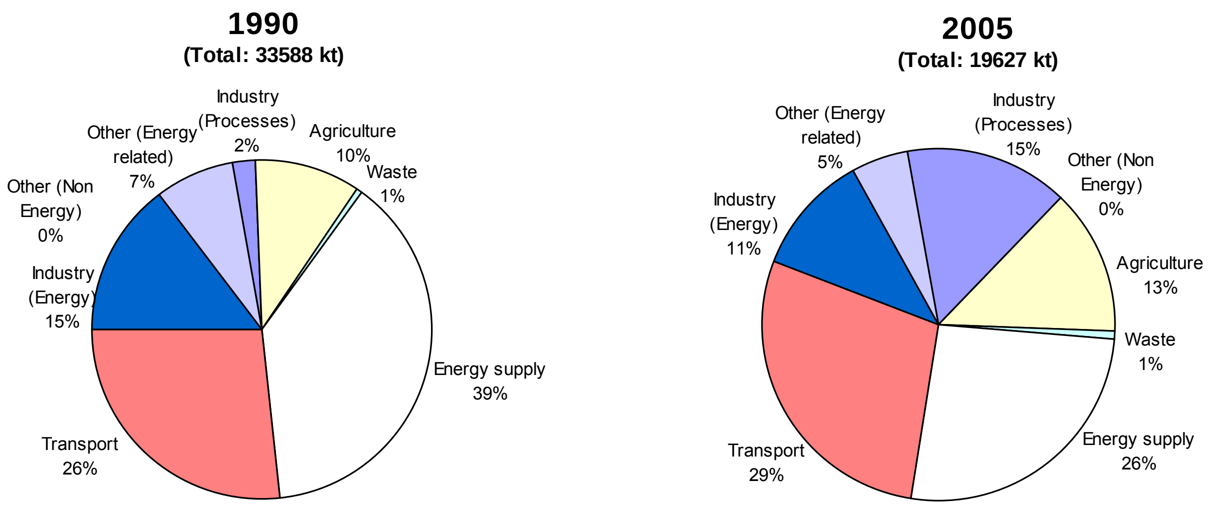


Fig: 2b Secondary particulate matter



Source: EEA/ETC-ACC 2007.

1. Indicator assessment

Energy-related particulate matter emissions (i.e. aggregated primary and secondary PM_{10}) in the EU-27 have fallen by 53 % between 1990 and 2005, although energy-related sectors were still responsible for 70 % of total PM_{10} particulate matter emissions to the atmosphere in 2005 (Fig 3). Of the specific energy-related particulate matter emissions in 2005, the most significant contributing pollutants were NO_x and SO_2, which together were responsible for almost 90% of the total energy related emissions (see also EEA, 2008).

Transport and Energy supply represent the sectors with the highest particulate matter emissions across the EU-27 and the EEA (Fig 4).

The majority of the reduction in emissions of energy-related particulate matter pollutants between 1990 and 2005 came from the energy supply sector (in both absolute and percentage terms), although the other sectors also decreased emissions significantly during this period (Fig 1). Overall, the reduction in emissions of energy-related particulate matter pollutants has mainly been achieved through a combination of using 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 road vehicles equipped with catalytic converters.

Emissions from transport decreased in the EU-27 by 36 % between 1990 and 2005, 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 2005 and 2010 (despite an increasing popularity of diesel vehicles in many countries), as improved vehicle engine technologies continue to be 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, do 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 PM_{10} in most of the urban areas in the EEA region are expected to remain well above the short-term limit air quality values (EEA 2006). Substantial further reductions in all sectors are therefore needed to reach the air quality 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 10 µm 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

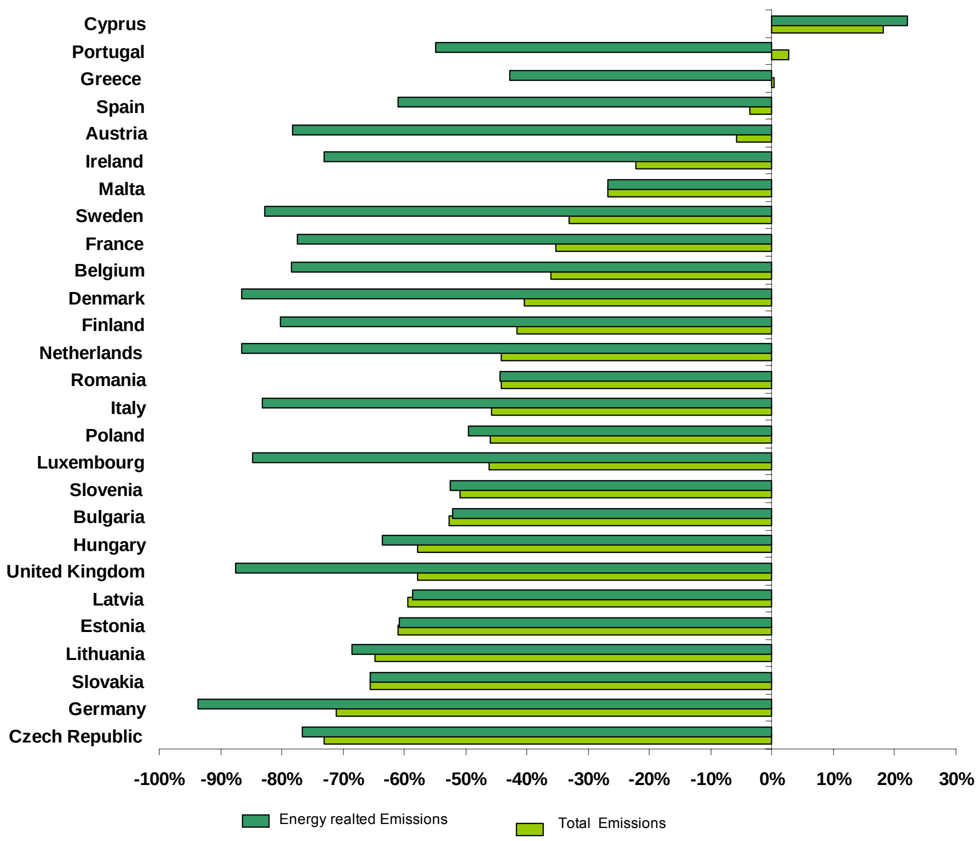
Levels of fine particulate matter and precursor emissions are controlled in the European Union by 3 main types of regulation:

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

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 limits and targets exist for the reduction of SO_2, NO_x and NH_3 emissions, including the National Emissions Ceiling (NEC) Directive (2001/81/EC) and the Gothenburg Protocol of the UNECE LRTAP Convention (UNECE 1999). These are discussed further in factsheet EN06. As part of the review of the NEC Directive that is currently taking place, the feasibility of introducing national emission ceiling targets for particulate matter is being investigated. A proposal for the revised directive is expected in spring 2008.

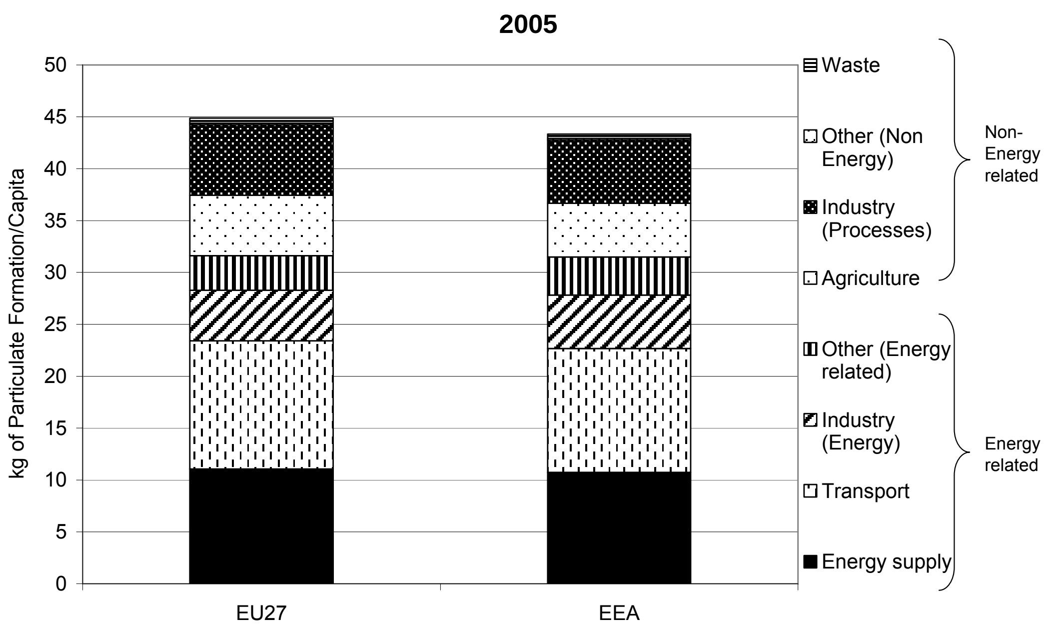
Fig. 3: Overall change in emissions of (primary and secondary) particulate matter by country, 1990-2005



Note: The graph shows the emissions of primary PM10 data, and emissions of secondary PM10 precursors (SO2 and NOx and NH3) each weighted using aerosol formation factors (according to de Leeuw, 2002) NOx = 0.88, SO2 = 0.54 and NH3 = 0.64.

Source: EEA/ETC-ACC 2007

Fig. 4: Particulate emissions (primary and secondary) per capita by sectors, 2005



Source: EEA/ETC-ACC 2007, Eurostat, 2007

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 (2008). Core Set Indicators (http://themes.eea.europa.eu/IMS/CSI)
- EEA (2006). Joint EMEP/CORINAIR Atmospheric Emission Inventory Guidebook, 3rd edition. EEA Technical Report No. 11/2006 (http://reports.eea.europa.eu/EMEPCORINAIR4/en/page002.html).
- EEA (2006). Exceedance of air quality limit values in urban areas. Core Set of Indicators (CSI 004) - July 2006 Assessment.
- EMEP (2005). 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 (LRTAP Convention), 2007 data submission. Base data are available on the EMEP website (http://webdab.emep.int/). Where primary PM_{10} data was not available, (for countries Bulgaria, Greece, Luxembourg, Malta, Romania and Turkey) national primary PM_{10} emission totals and sector data estimates have been obtained from the RAINS PM_{10} model using CAFE_Baseline scenario NEC_NAT_CLEV4(NEC04) (http://www.iiasa.ac.at/rains/). Total energy consumption data from Eurostat http://epp.eurostat.ec.europa.eu/ 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.europa.eu/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 EEA/ETC-ACC where necessary using simple interpolation techniques (see 6).

3. Geographical coverage: EU-27. Other analyses include data for EFTA-4 (Iceland, Liechtenstein, Switzerland and Norway) Croatia, FYR of Macedonia and Turkey. The EEA-32 country grouping includes EU-27, EFTA-4 and Turkey.

4. Temporal coverage: 1990-2005

5. Methodology and frequency of data collection: Annual country data submissions to UNECE/LRTAP Convention/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 2006).

6. Methodology of data manipulation: 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 (kilotonnes - kt). EEA/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.europa.eu/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.

Quality information

7. Strengths and weaknesses (at data level): Strength: officially reported data following agreed procedures and Emission Inventory Guidebook (EEA 2005), 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 2005). 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 2005). 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