EN08 Emissions (CO_2, SO_2 and NO_x) intensity of public conventional thermal power (electricity and heat) production

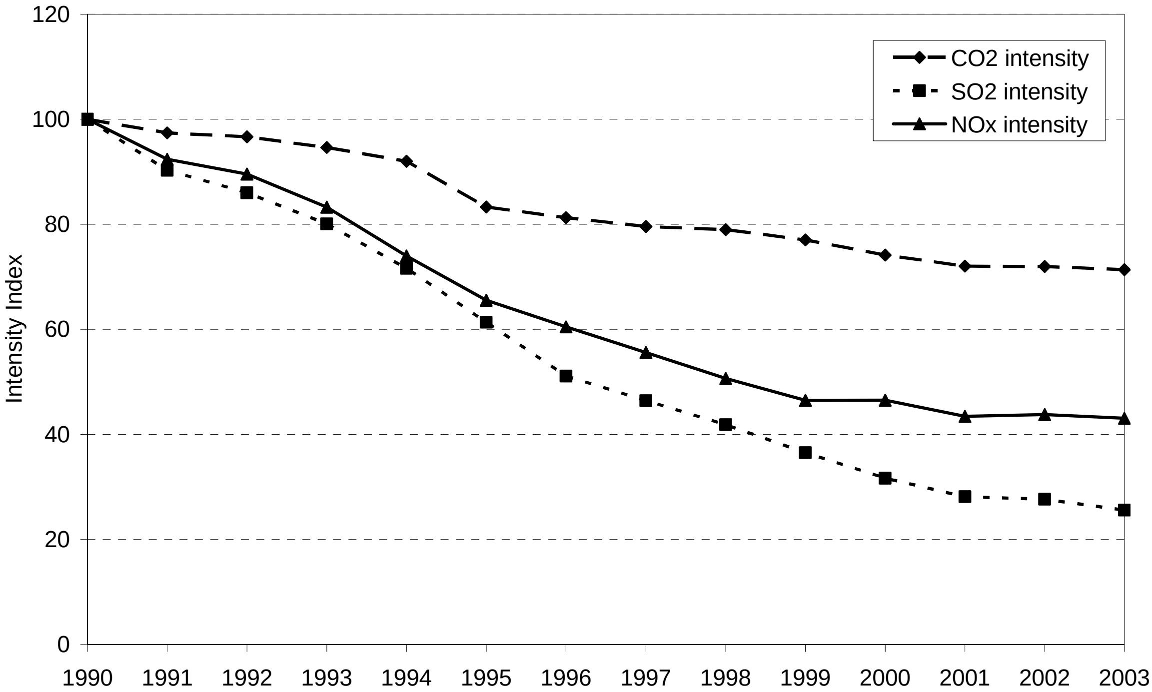
Key message

The emissions intensity of carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrogen oxides (NO_x) from public conventional thermal power plants has decreased substantially since 1990, particularly in the case of SO_2 and NO_x. This is primarily due to a decline in the use of coal, and replacement of old, inefficient coal plant as well as the use of abatement techniques. However, in recent years a rise in the coal-fired electricity production has acted to slow the decline in emissions intensity. Rising overall electricity consumption has also acted to partly offset the environmental benefits from improvements in emissions intensity.

Rationale

Electricity and heat production from public thermal power plants is a significant source of both air pollutants and greenhouse gas emissions. Reducing the emissions per unit of electricity and heat produced (emissions intensity) of these plants can play an important role in helping to reduce their environmental impacts.

Fig. 1: Emissions intensity of public conventional thermal power production, EU-25



Data source: European Environment Agency – European topic centre on air and climate change, and Eurostat

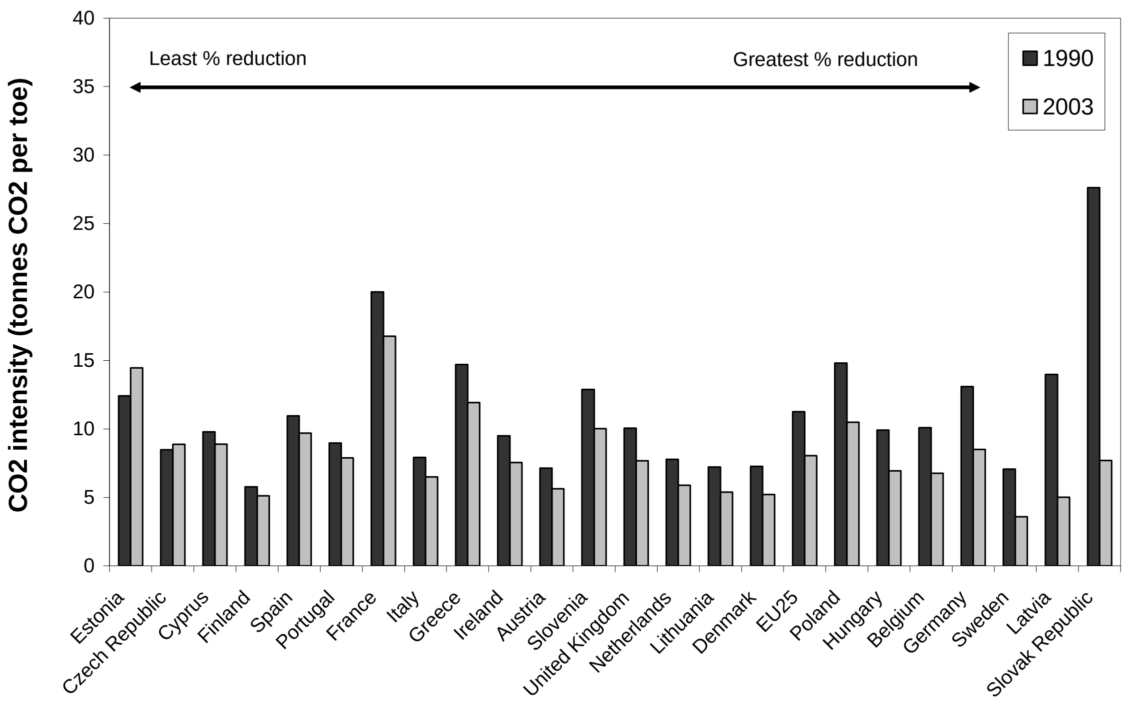
Notes: The emissions intensity of conventional public thermal power production is the level of CO_2, SO_2 or NO_X emissions per unit of power (electricity and heat) produced by public thermal power stations. The emission intensities are calculated as the ratio of CO_2, SO_2 and NOX emissions from public power production to the output of electricity and heat from public conventional thermal power production. Public thermal power stations generate electricity and/or heat for sale to third parties, as their primary activity. They may be privately or publicly owned. For Luxembourg and Malta there are no emissions data for SO_2 or NO_x and so these countries are not included in the graph. There are also no CO_2 emissions data for Malta.

1. Indicator assessment

Emissions of carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrogen oxides (NO_x) per unit of electricity and heat produced by public conventional thermal power plants (i.e. the emissions intensity) decreased substantially during the period 1990-2003, with the majority of the reduction achieved during the 1990s and improvements slowing down since the late 1990s onwards. The reductions in SO_2 and NO_x emissions intensity have been particularly significant, influenced by emission abatement techniques such as flue gas desulphurisation and low-NO_X burners, and the greater use of low-sulphur fuels (see EN09 for the quantitative contribution of each factor to reduced emissions). Emission reductions have also been helped by some switch in electricity production from coal and oil to natural gas, prompted by the liberalisation of energy markets and improvements in the efficiency of electricity production. However, action is still required to ensure further reductions, particularly in the new Member States, as on average the emissions intensities of all pollutants, and in particular SO_2, in these countries are still higher than the average for the older Member States.

The intensity of carbon dioxide emissions from public conventional thermal power plants in the EU-25 decreased by 28.6 % from 1990 to 2003 (i.e. at an average annual rate of 2.6 %) due to improvements in all Member States except the Czech Republic and Estonia. This was mainly as a result of the closure of old and inefficient coal-fired plants and their replacement with either newer, more efficient coal-fired plants or new gas-fired plants. The latter was primarily driven by economic decisions, as over this period the costs of electricity produced from gas-fired plants have generally been less than for coal- and oil-fired plants, leading to a preference for new gas plants. However, increased gas prices towards the end of the period have led to higher utilisation of existing coal plants in some EU countries and, as a result, the CO_2 emissions intensity has changed little since 2001. Typically natural gas has approximately 40 % less carbon content than coal, and 25 % less carbon content than oil. Combined cycle gas turbine (CCGT) technology, the technology most often used with new gas power plants, can achieve at least 55-60 % efficiency compared with the 35-40 % efficiency of traditional coal-fired power plant, and thus further reduce the emissions intensity. Latvia and Slovakia achieved the largest percentage reduction in the intensity of carbon dioxide emissions in the EU-25, with an average annual decrease of 12.9 % and 9.4 % respectively. In Latvia this was largely due to greater use of gas at the expense of oil for electricity production, while in Slovakia gas use increased at the expense of coal and lignite. Sweden had the lowest CO_2 emissions intensity in 2003, which was mainly due to a negligible share of coal and lignite in power production and a high share of renewable energies (see EN27). With the exception of France, which produces very little public conventional thermal power, Estonia and Greece have the highest carbon intensity of all Member States. This is due to the continuing dominance of coal and lignite (92 % in Estonia and 71 % in Greece) as well as a high share of oil in Greece (16 %) as a fuel for public conventional thermal power production.

Fig. 2: Emission intensity of carbon dioxide from public conventional thermal power production

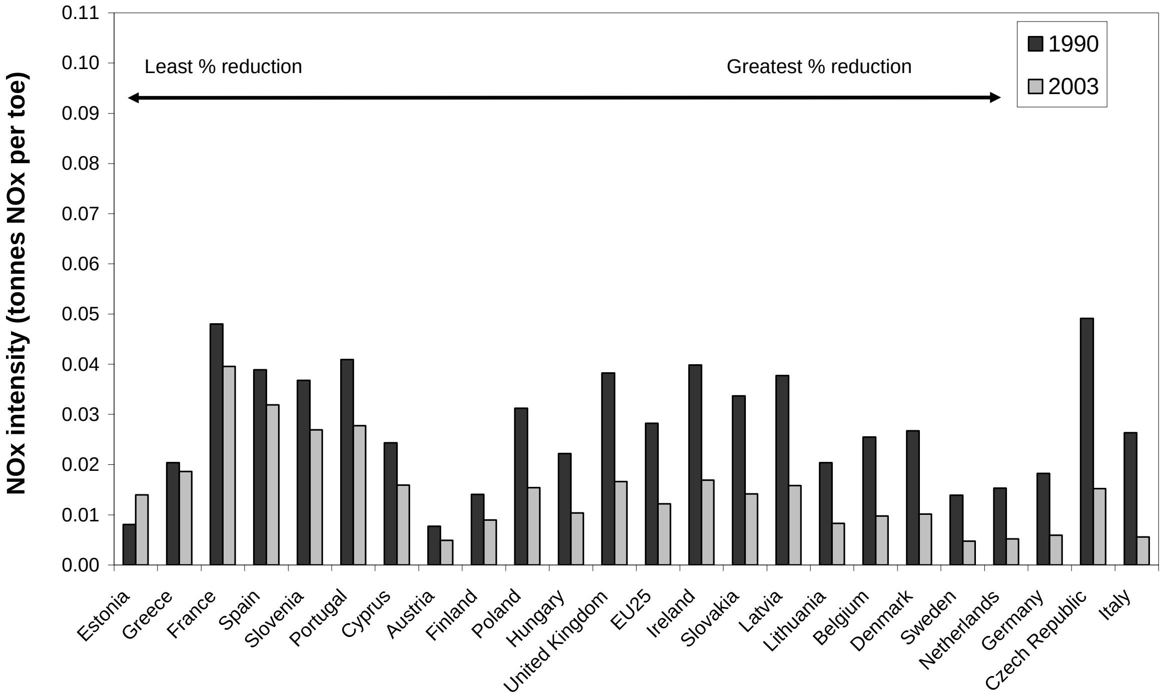


Data source: European Environment Agency – European Topic Centre on Air and Climate Change, and Eurostat

Notes: No emissions data for Luxembourg. Emissions intensity is calculated as the amount of pollutant produced (in tonnes) from public electricity and heat production divided by the output of electricity and heat (in toe) from these plants.

During the period 1990-2003, the emissions intensity of nitrogen oxides from public conventional thermal plants decreased at an average rate of 6.3 % per year, resulting in a total reduction in emissions intensity of 57 %. This was due to the increased use of end-of-pipe abatement techniques such selective catalytic reduction, low-NO_x burners and the use of less polluting fuels in public conventional thermal power production in many Member States. Low-NO_x burners reduce emissions by controlling the mixing and proportions of fuel and air in the combustion process and typically can reduce NO_x emissions by up to 40 %. Selective catalytic reduction uses a chemical reaction involving ammonia to convert NO_x to nitrogen and water and removals of up to 90 % can be achieved. NO_x intensities fell in all Member States (except Estonia), particularly strong in Italy and the Czech Republic. While this reduction was mainly due to large increases in the use of gas for electricity production in Italy, in the Czech Republic a combination of constructing new fluidised bed boilers and implementing NO_x control technologies on existing boilers has significantly reduced NOx emissions. The country with the highest NO_x intensity is France, although it produces relatively small amounts of public conventional thermal power, mostly from coal and oil.

Fig. 3: Emission intensity of nitrogen oxides from public conventional thermal power production

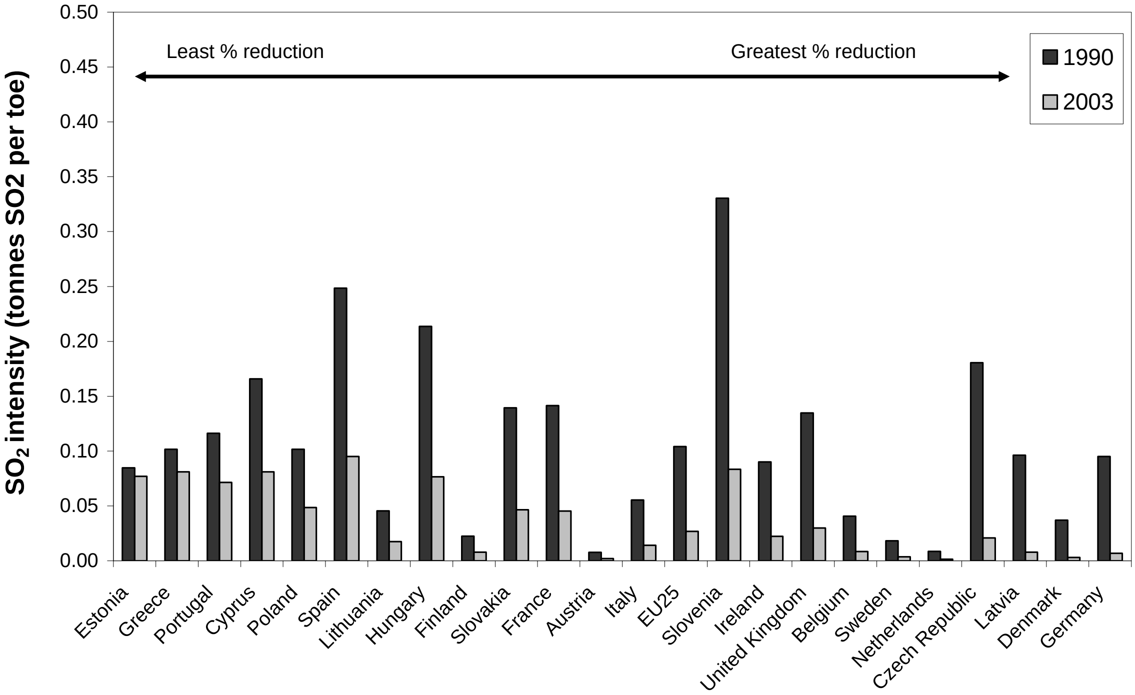


Data source: European Environment Agency – European Topic Centre on Air and Climate Change, and Eurostat

Note: No emissions data for Luxembourg, Malta or Iceland. Emissions intensity is calculated as the amount of pollutant produced (in tonnes) from public electricity and heat production divided by the output of electricity and heat (in toe) from these plants.

The emissions intensity of sulphur dioxide from public conventional thermal power plants decreased by 74 % from 1990 to 2003 (i.e. at an average annual rate of 10 %). This is the largest decrease in emissions intensity of all emissions from public conventional thermal power plants. Germany and Denmark also showed large reductions in emissions intensity. In Denmark this was through increased use of natural gas, while in Germany the SO_2 reductions have been due mainly to the closure of old, inefficient lignite-based power plants following reunification, but also due to the extensive use of flue gas desulphurisation technologies. Flue gas desulphurisation is an abatement end-of-pipe technology, which is fitted to large combustion plants, such as power plants. The application of this technology has been driven by national efforts to reduce SO_2 emissions and also in response to the implementation of EU Directive 88/609/EEC (superseded by Directive 2001/80/EC) on the limitation of emissions of certain atmospheric pollutants into the air from large combustion plants. Spain and Slovenia had the highest SO_2 emissions intensities in the EU-25 in 2003, influenced by the use of high sulphur content coal and lignite. In Slovenia, coal use was also very significant.

Fig. 4: Emissions intensity of sulphur dioxide from public conventional thermal power production



Data source: European Environment Agency – European Topic Centre on Air and Climate Change, and Eurostat

Note: No emissions data for Luxembourg, Malta or Iceland. Emissions intensity is calculated as the amount of pollutant produced (in tonnes) from public electricity and heat production divided by the output of electricity and heat (in toe) from these plants.

According to baseline projections (EEA, 2005), the CO_2 emissions intensity of public conventional thermal power production in the EU-25 is expected to continue to decline, at an average annual rate of 1.3 % over the period 2000-2010. After 2010, the CO_2 intensity is expected to continue declining at a slower rate until 2020. New policy initiatives and the widespread implementation of competition in the energy markets will encourage further switching to low-carbon fossil fuels (mainly natural gas) and improve the efficiency of public conventional thermal power production.

In the longer term, the prospects for continuing this trend look less certain. Baseline projections suggest a slight rise in CO_2 emissions intensity over the period 2020-2030 whereas the Low Carbon Energy Pathway (LCEP) scenario variant of the projections (EEA, 2005) shows a greater reduction in emissions intensity, particularly over the period 2010 to 2020 and the decline continues until 2030, as the energy system responds to the rising carbon permit price. In absolute terms the CO_2 emissions intensity under the LCEP by 2030 is expected to reach broadly 60 % of the value in 2000, whereas in the baseline scenario this only drops to around 80 % by the same point.

2. Indicator rationale

2.1 Environmental context

Carbon dioxide is the most abundantly produced greenhouse gas. Increased greenhouse gas emissions lead to higher concentrations in the atmosphere, which contributes to climatic change, including increased temperatures and more variable and erratic weather patterns. The potential consequences of climate change include sea-level rise and increased flooding or drought. Climate change will have adverse impacts on biodiversity with species loss or migration and may also lead to new patterns of disease e.g. return of malaria to southern and northern Europe. Changes in the availability of water resources could have implications for public supply and other uses within the economy e.g. agricultural supply and tourism development.

Emissions of sulphur dioxide and nitrogen oxides are the main cause of acid deposition leading to changes in soil and water quality and damage to forests, crops and other vegetation, and to adverse effects on aquatic ecosystems in rivers and lakes. Acidification also damages buildings and cultural monuments and potentially has links to human respiratory diseases. Other health impacts can arise if acidification affects groundwater used for public water supply.

2.2 Policy context

Although there are no specific EU targets for reducing the emissions intensity of public thermal power production, such reductions will play an important role in helping the EU to meet its commitments under the Kyoto protocol of the United Nations Framework Convention on Climate Change and the National Emissions Ceiling Directive. The latter requires the introduction of national emission ceilings (upper limits) for emissions of SO_2 and NO_x (as well as NH_3 and NMVOCs) in each Member State, as well as setting interim environmental objectives for reducing the exposure of ecosystems and human populations to damaging levels of the acid pollutants. Targets for the new Member States are temporary and are without prejudice to the review of the NEC Directive which is to be completed in 2005-2006. In terms of the energy sector, the most relevant NEC Directive targets for the EU-25 as a whole are for SO_2 and NO_x emissions reductions of 74 % and 53 % respectively by 2010 from 1990 levels.

A number of EU policies have an impact on the emissions intensity of public thermal power plants, including the Large Combustion Plant Directive (2001/80/EC) which aims to control emissions of SO_2, NO_x and particulate matter from large (>50MW) combustion plants and hence favours the use of higher efficiency CCGT as opposed to coal plants; and plants covered under the IPPC Directive (96/61/EC) which are required to meet a set of emissions abatement and energy efficiency provisions through the use of best available technology not entailing excessive cost (BATNEEC).

The Directive establishing a scheme for greenhouse gas emission allowance trading within the Community (2003/87/EC) is primarily intended to help contribute to the European Union fulfilling its commitments under the Kyoto Protocol and will affect the CO_2 intensity. Under the Directive, Member States have to draw up a National Allocation Plan that will include setting caps on CO_2 emissions from all thermal electricity generating plants greater than 20 MW. A shift to less carbon intensive fuels for electricity generation, such as gas, and improvements in efficiency are important options to help generators meet their requirements under the directive, but these will also have the effect of helping to reduce the emissions intensity of SO_2 and NO_x.

References

European Commission (2004) European energy and transport – scenarios on key drivers, Directorate General for Transport and Energy

EEA (2005) Climate change and a low-carbon European energy system, European Environment Agency report No 1/2005.

EEA (2005b) Annual European Community greenhouse gas inventory 1990–2003 and inventory report 2005, European Environment Agency Technical Report No4/2005

EEA (2004). Joint EMEP/CORINAIR Atmospheric Emission Inventory Guidebook, 3rd edition. EEA Technical Report No. 30

EMEP (2005). Transboundary Acidification, Eutrophication and Ground Level Ozone in Europe in 2003. EMEP Status Report 2005. ISSN 0806-4520

European Commission, Integrated Pollution Prevention and Control (IPPC) Draft reference document on Best Available Techniques for large combustion plants, Joint Research Centre, March 2003.

Energy overviews for various countries produced by the Office of Fossil Energy, U.S. Department of Energy

Meta data

Technical information

1. Data source:
Historical emissions - European Environment Agency - European Topic Centre on Air and Climate change.
Historical energy data - Output of heat and electricity from public thermal power stations from Eurostat http://europa.eu.int/comm/eurostat/. At the end of May 2006 Eurostat published a revised time series for Latvia. There were important corrections for the year 1990 in the energy balance. These changes for Latvia have been taken into account as much as possible. However, the EU-10 and EU-25 aggregates could not be updated. Changes to the EU aggregates are likely to be limited as in 1990 the total energy consumption in Latvia represented approximately 3 % and 0.5 % of the total energy consumption in the EU-10 and EU-25, respectively.
Projection data for energy and emissions: European Environment Agency (2005) – baseline projections are consistent with European Commission (2004).

2. Description of data:
Historical emissions of CO_2, NO_X and SO_2 from the common reporting format category 1A1a Public electricity and heat production. Output from public thermal power stations covers gross electricity generation and any heat also produced by public thermal power stations. Public thermal power stations generate electricity and/or heat for sale to third parties as their primary activity. They may be privately or publicly owned. The gross electricity generation is measured at the outlet of the main transformers, i.e. the consumption of electricity in the plant auxiliaries and in transformers is included.
Emissions intensity is calculated by dividing the emissions of each pollutant from public electricity and heat production (CRF 1A1a) by the output from public thermal power stations.
The PRIMES model was used by the EEA to analyse possible future developments of the European energy sector, including a baseline scenario without a permit price and the low carbon energy pathway (LCEP) scenario. It describes the least-cost response of the EU-25 energy system to the introduction of a carbon permit price that rises to EUR 65/t CO_2-equivalent by 2030.

3. Geographical coverage: EU-25 and Romania, Bulgaria and Norway

4. Temporal coverage: 1990 to 2003 and projections to 2030.

5. Methodology and frequency of data collection:
CO_2 emissions data are annual official data submission to UNFCCC and EU Monitoring mechanism. Combination of emission estimates based on volume of activities and emission factors. Recommended methodologies for emission data collection are compiled in the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997). supplemented by the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000) and UNFCCC Guidelines (UNFCCC, 2000).
SO_2 and NO_x emissions data are 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 (2004).
Energy data collected annually by Eurostat. Eurostat definitions for energy statistics http://forum.europa.eu.int/irc/dsis/coded/info/data/coded/en/Theme9.htm.
Eurostat metadata for energy statistics: http://europa.eu.int/estatref/info/sdds/en/sirene/energy_base.htm.

6. Methodology of data manipulation, including making 'early estimates':
ETC-ACC gap-filling methodology. Where countries have not reported data for one, or several years, data for emissions from public conventional thermal power production has been calculated as a proportion of the emissions from all energy industries (which includes emissions from refineries etc) by applying a scaling factor. This scaling factor has been calculated as the ratio of emissions from public conventional thermal power production to emissions from all energy industries for a year in which both data sets exist (usually 2002). It is recognised that the use of gap-filling can potentially lead to inaccurate trends, but it is considered unavoidable if a comprehensive and comparable set of emissions data for European countries is required for policy analysis purposes. Information on the gap filled data is shown in the section on data weaknesses.
Emission intensities are calculated as the ratio of CO_2, NO_x and SO_2 emissions of public conventional thermal power production divided by the electricity and heat output from public conventional thermal power production.
Average annual rate of growth calculated using: [(last year / base year) ^ (1 / number of years) –1]*100.Average

Quality information

7. Strengths and weaknesses (at data level):
Emissions: Officially reported data following agreed procedures. E.g. CO_2 data are based upon annual submissions under the UNFCCC, and SO_2 and NO_x emissions data are annual submissions to UNECE/CLRTAP/EMEP.
Energy data have been traditionally compiled by Eurostat through the annual Joint Questionnaires, shared by Eurostat and the International Energy Agency, following a well established and harmonised methodology. Methodological information on the annual Joint

Questionnaires and data compilation can be found in Eurostat's web page for metadata on energy statistics.
http://europa.eu.int/estatref/info/sdds/en/sirene/energy_sm1.htm

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

Indicator uncertainty (historic data):
The emissions intensity of power production is calculated as the ratio of emissions to total electricity and heat output. For electricity data (unlike that for overall energy consumption) 1990 refers to the West part of Germany only.
The IPCC (IPCC, 2000) suggests that the uncertainty in the total GWP-weighted emission estimates, for most European countries, is likely to be less than ± 20 %. The IPCC believes that the uncertainty in CO_2 emission estimates from fuel use in Europe is likely to be less than ± 5 %. Total GHG emission trends are likely to be more accurate than the absolute emission estimates for individual years. The IPCC suggests that the uncertainty in total GHG emission trends is ± 4 % to 5 %. This year for the first time uncertainty estimates were calculated for the EU-15 in EEA (2005b). The results suggest that uncertainties at EU-15 level are between ± 4 % and 8 % for total EU-15 greenhouse gas emissions. For energy related greenhouse gas emissions the results suggest uncertainties between ± 1 % (stationary combustion) and ± 11 % (fugitive emissions). For public electricity and heat production specifically, which is the focus of the indicator, the uncertainty is estimated to be ± 3 %. For the new Member States and some other EEA countries, uncertainties are assumed to be higher than for the EU-15 Member States because of data gaps.
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).
In contrast, NOx emission estimates in Europe are thought to have higher uncertainty, as the NOx 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).
For all emissions the trend is likely to be much more accurate than individual absolute annual values - the annual values are not independent of each other. However not all countries apply changes to methodologies back to 1990.

9. Overall scoring (1 = no major problems, 3 = major reservations):
   - Relevance: 1
   - Accuracy: 2
   - Comparability over time: 2
   - Comparability over space: 2