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

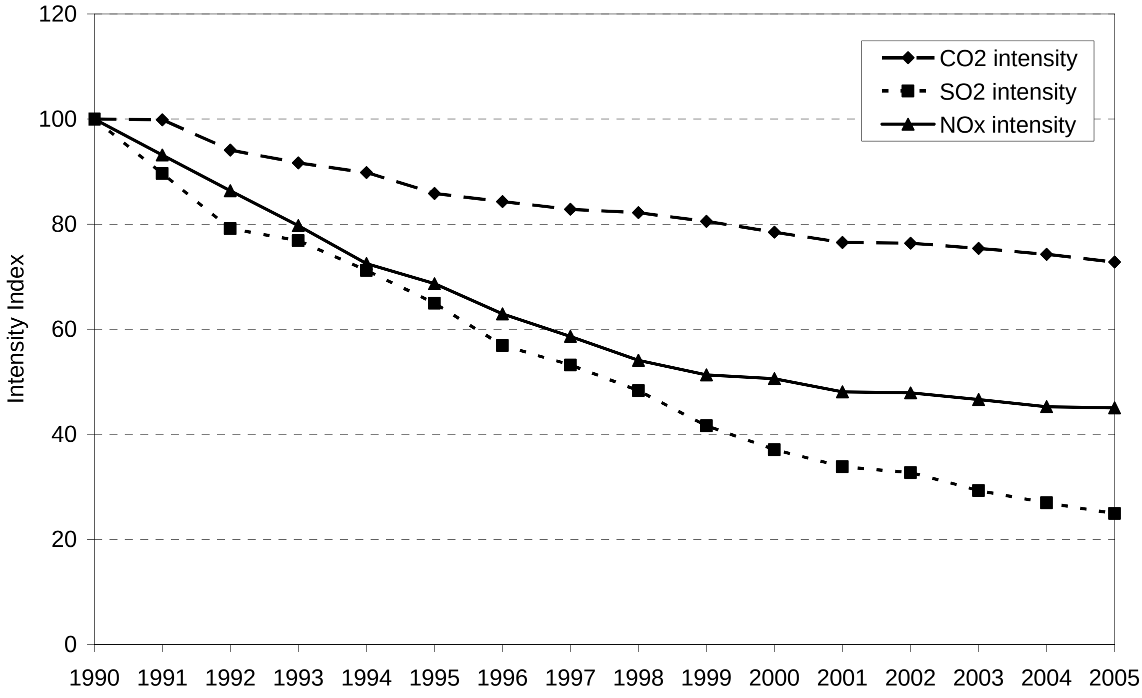
Key message

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. While CO_2 intensity has decreased, CO_2 emissions have increased in real terms by around 6% between 1999-2005.

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.

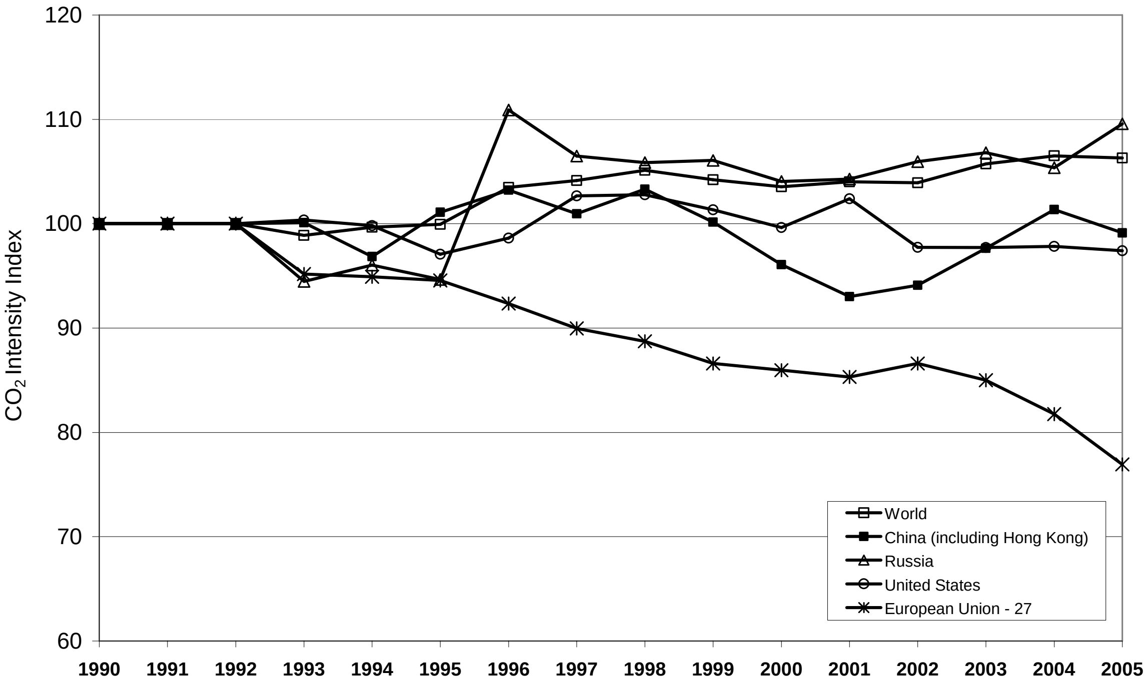
Fig. 1: Emissions intensity of public conventional thermal power production, EU-27



Data source: EEA – 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 NO_X 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. No data are available for Luxembourg and so data for this country is not included in the chart.

Fig. 2: CO_2 Emissions intensity of Electricity and Heat Output



Data source: IEA – International Energy Agency

Notes: The emissions intensity of Electricity and Heat Output is the level of CO_2, emissions per kWh of Electricity and Heat produced.

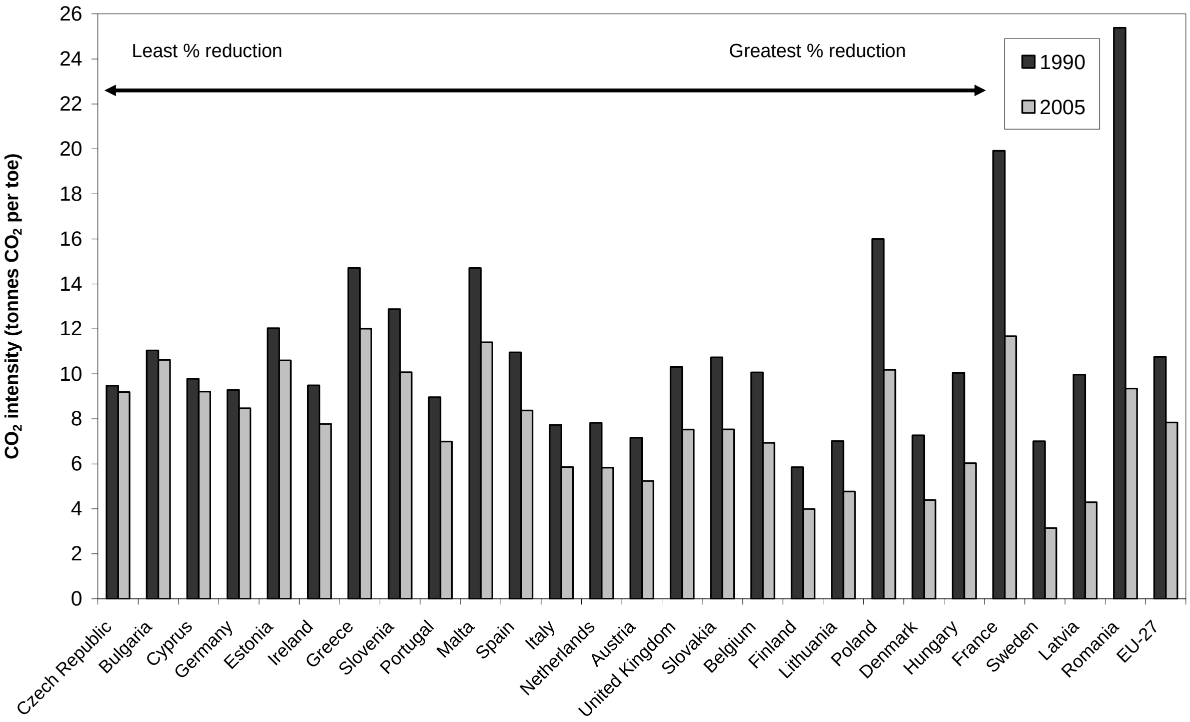
1. Indicator assessment

Across the EU27, 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 1990-2005, with the majority of the reduction achieved during the 1990s and improvements slowing down from 2000 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-27 decreased by about 27% from 1990 to 2005 due to improvements in all Member States. This reduction has generally occurred 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 typically 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 relatively 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. Romania, Latvia and Sweden achieved the largest percentage reduction in the intensity of carbon dioxide emissions in the EU-27. Sweden had the lowest CO_2 emissions intensity in 2005, which was mainly due to a negligible share of coal and lignite in public conventional thermal power production (see EN27). With the exception of France which produces very little public conventional thermal power, Greece and Malta have the highest carbon intensity of all Member States. In Greece this is due to the continuing dominance of coal and lignite (59.6%) as well as a high share of oil (14.1%) as fuels for public conventional thermal power production. Malta derives all of its public conventional thermal power from oil. Of the little public conventional thermal power produced in France, almost all comes from coal and lignite (see EN-27 for further details on fuel use by countries).

On a global scale the intensity of carbon dioxide emissions from Electricity and Heat production is increasing from 1990 to 2005. The intensity of carbon dioxide emissions from Electricity and Heat production decreased in China (including Hong Kong) and the United States but shows an increase in Russia.

Fig. 3: Emission intensity of carbon dioxide from public conventional thermal power production

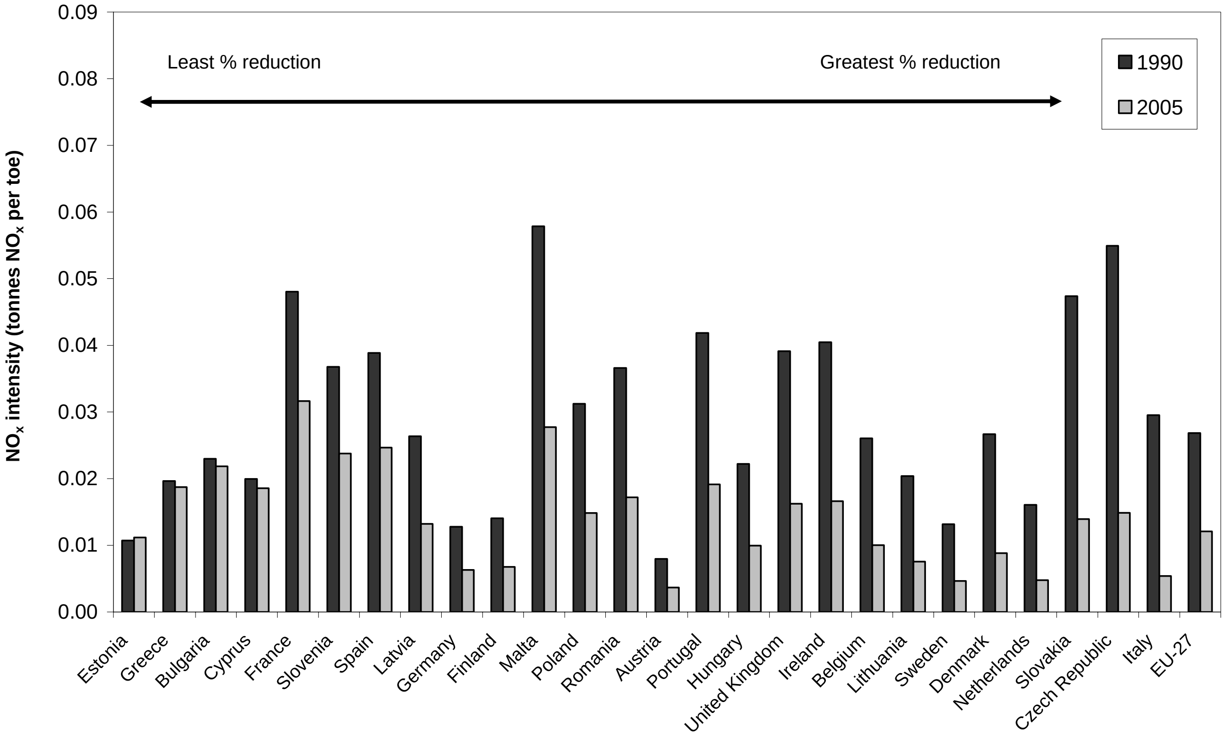


Data source: EEA – European Topic Centre on Air and Climate Change, and Eurostat

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 1990-2005, the emissions intensity of **nitrogen oxides** from public conventional thermal plants in the EU-27 decreased by 55%. 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), with the largest decreases occurring 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 countries with the highest NO_x intensity are France, which although it produces relatively small amounts of public conventional thermal power, this is mostly from coal, and Malta, which derives all of its for public conventional thermal power from oil.

Fig. 4: Emission intensity of nitrogen oxides from public conventional thermal power production

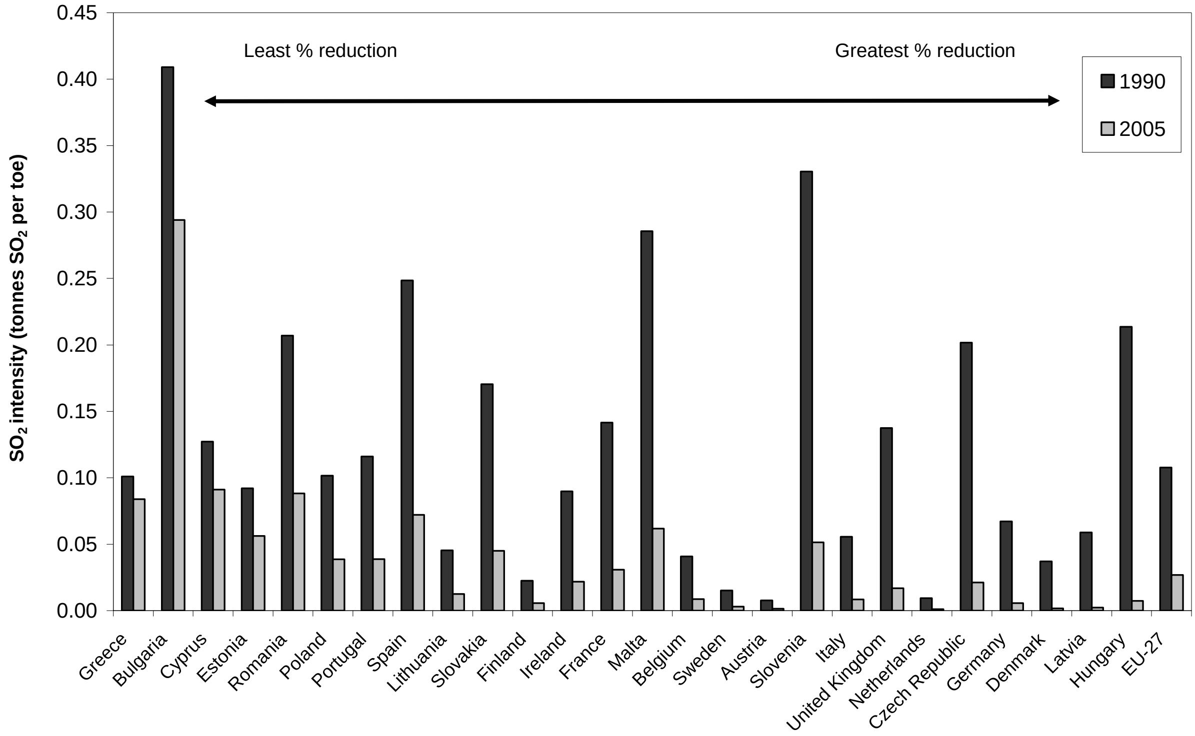


Data source: EEA – European Topic Centre on Air and Climate Change, and Eurostat

Note: 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. No emissions data for Luxembourg or Iceland. For Malta, only 2003 to 2005 data are available; the 2003 value appears above as the 1990 value.

The emissions intensity of **sulphur dioxide** from public conventional thermal power plants decreased by 75% from 1990 to 2005, a significantly larger reduction than occurred for either CO_2 or NO_X emissions intensities from public conventional thermal power plants. In particular, Hungary, Latvia, Denmark and Germany showed large reductions in emissions intensity. Hungary significantly increased its use of natural gas and decreased its use of oil while in Latvia there was a substantial decrease in the use of coal, lignite and oil. In Denmark the SO_2 emissions reductions occurred through a fifteen-fold increase in the use of natural gas. In Germany the 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. Bulgaria had by far the highest SO_2 emissions intensities in 2005, due largely to an increasingly heavy reliance on high sulphur content coal and lignite to generate public conventional thermal power, with an 80% reduction in the use of natural and derived gas from 1990-2005. High SO_2 emissions intensities in Cyprus, Romania and Greece were influenced by the use of high sulphur oil in Cyprus and coal and lignite in Romania and Greece.

Fig. 5: Emissions intensity of sulphur dioxide from public conventional thermal power production



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

Note: 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. No emissions data for Luxembourg or Iceland. For Malta, only 2003 to 2005 data are available; the 2003 value appears above as the 1990 value.

According to the European Commission's PRIMES energy projections (2006), the CO_2 emissions intensity of public conventional thermal power production in the EU-27 is expected to continue to decline, at an average annual rate of 1.4 % over the period 2000-2010. After 2010, the CO_2 intensity is expected to continue declining at a faster rate (1.7%) until 2020. New policy initiatives and the widespread implementation of competition in the energy markets are predicted to 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. PRIMES energy projections suggest a slower rate of decline in CO_2 emissions intensity over the period 2020-2030 (0.3%). Under a low carbon energy pathway (EEA 2005), a greater reduction in emissions intensity, continuing to 2030, would be expected as the energy system responds to rising carbon permit prices. The decline in CO_2 emissions intensity is predicted to be greater in the new Member States (1.8% 2010-2020 and 1.3% 2020-2030).

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 SO2 and NOx (as well as NH3 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 on-going review of the NEC Directive which should result in a proposal for a revised Directive in 2008. Targets for Bulgaria and Romania are provisional and not binding. Hence, the existing EU25 NECD Target has been used in the following analysis.

In terms of the energy sector, the most relevant NEC Directive targets for the EU-25 (excluding Bulgaria and Romania) are for SO_2 and NO_x emissions reductions of 74% and 53% respectively by 2010 from 1990 levels. Bulgaria and Romania have provisional targets for SO_2 and NO_x emissions reductions.

A number of EU policies have an impact on the emissions intensity of public thermal power plants, including the Large Combustion Plant (LCP) 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 Integrated Pollution Prevention and Control (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). New installations, and existing installations which are subject to "substantial changes", have been required to meet the requirements of the IPPC Directive since 30 October 1999. Other existing installations must be brought into compliance by 30 October 2007. The LCP Directive requires significant emission reductions from "existing plants" (licensed before 1 July 1987) to be achieved by 1 January 2008.

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, each Member State drew up National Allocation Plans for 2005-2007 and again for 2008-2012 that set 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, and these will also have the effect of helping to reduce the emissions intensity of SO_2 and NO_x

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IEA – International Energy Agency 2008

Meta data

Technical information

1. Data sources:
Historical emissions - 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 transmissions of air pollutants in Europe) Convention on Long-range Transboundary Air Pollution (CLRTAP), submission 2007. Base data are available on the EMEP website (http://webdab.emep.int/). CO_2 emissions are from officially reported national total and sectoral emissions, reported to UNFCCC and EU Monitoring Mechanism, submission 2007 (National Annual Greenhouse Gas Inventories).
Historical energy data - Output of heat and electricity from public thermal power stations from Eurostat http://europa.eu.int/comm/eurostat/.
Projection data for energy and emissions - Baseline projections are from the PRIMES energy model European Commission (2006).

2. Description of data:
Historical emissions of CO_2, NO_X and SO_2 from the 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 (sector 1A1a) by the output from public thermal power stations.

3. Geographical coverage: EU-27, Turkey, Norway and Iceland. No data for Liechtenstein or Switzerland.

4. Temporal coverage: 1990 to 2005 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, 2006), 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 (2006).
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 2005). 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.

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 %. Uncertainty estimates for the EU-15 were calculated by the EEA (2006). The results suggest that uncertainties at EU-15 level are between ± 4 % and 11 % for total EU-15 greenhouse gas emissions. For energy related greenhouse gas emissions the results suggest uncertainties between ± 2 % (stationary combustion) and ± 11 % (fugitive emissions). For public electricity and heat production specifically, which is the focus of the indicator, the CO_2 uncertainty is estimated to be ± 0.2 %. 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