EN09 Emissions (CO_2, SO_2 and NO_x) from public electricity and heat production – explanatory indicators

Key message

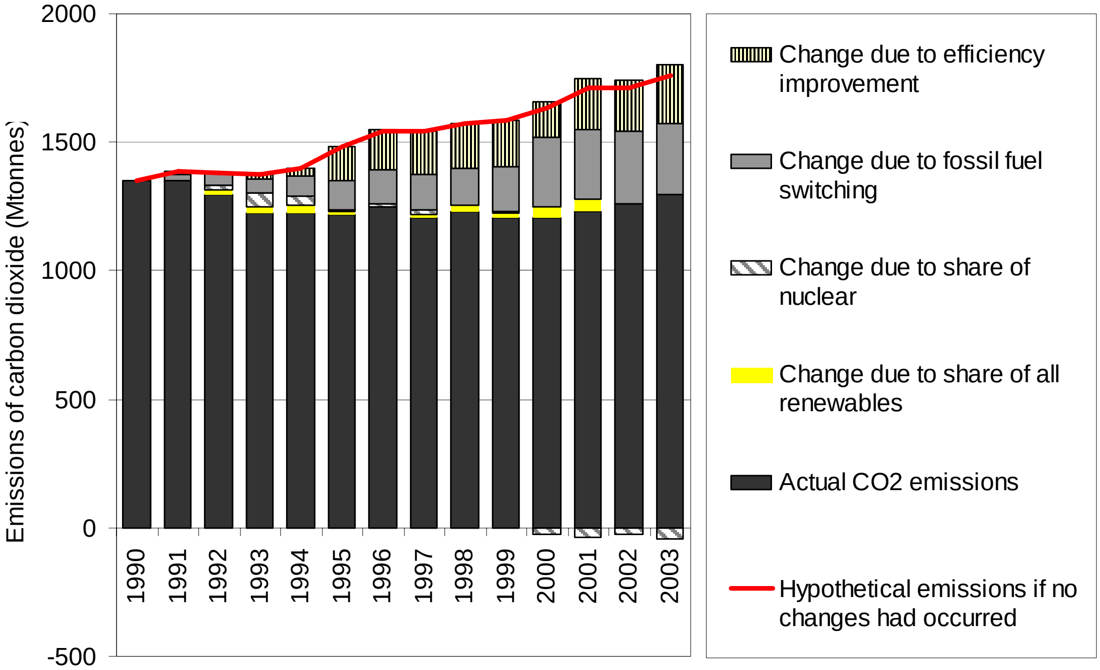
Between 1990 and 2003, EU-25 emissions of carbon dioxide, sulphur dioxide and nitrogen oxide from public electricity and heat production fell despite a 30 % increase in the amount of electricity and heat produced. CO_2 emissions decreased by almost 4 % from the 1990 baseline, as a result of fuel switching and efficiency improvements. SO_2 emissions fell by 66 %, due mainly to abatement techniques, use of low-sulphur fuels, and to a lesser extent, to fossil fuel switching. NO_x emissions fell by 42 %, primarily due to abatement techniques. Some emissions have risen in recent years due to increased utilisation of existing coal plant with higher emissions per unit of output. Current policies will need to be extended and enhanced and new measures will be required if further emission reductions in the long term are to be achieved (particularly for CO_2).

Rationale

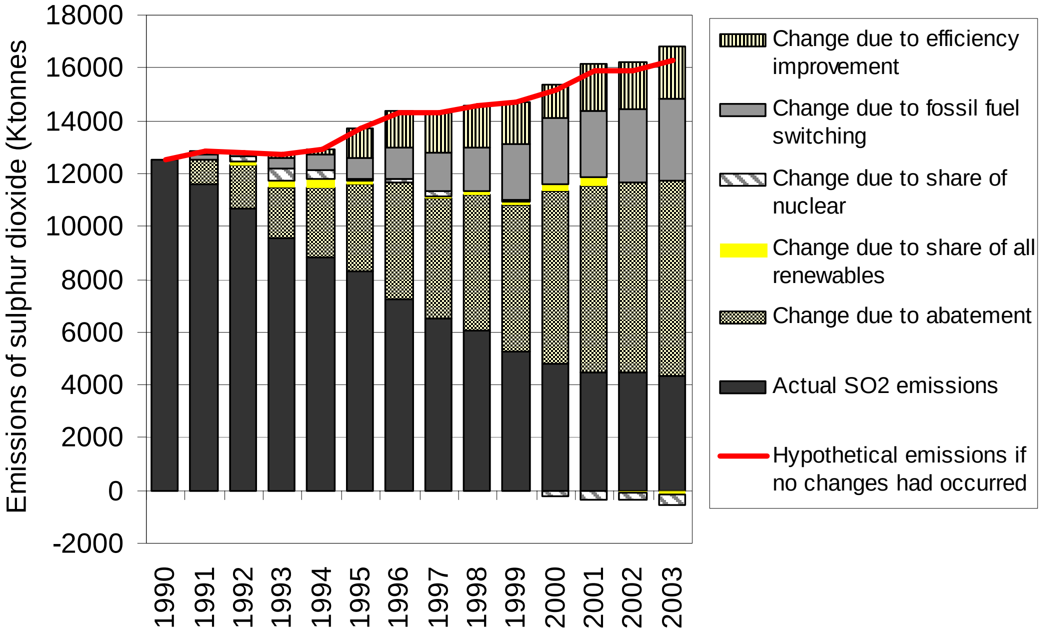
Electricity and heat production from public thermal power plants is a significant source of both air pollutants and greenhouse gas emissions. Reducing these emissions of the power sector is needed to achieve the greenhouse gas emission reductions of the whole society as agreed under the Kyoto Protocol and that of air pollutants as agreed under the NEC directive. Understanding what is driving the trend in emissions from public electricity and heat production can help identify successful policies for reducing its environmental impacts.

Fig.1: Estimated impact of different factors on the reduction in emissions of CO_2, SO_2 and NO_x from public electricity and heat production between 1990 and 2003, EU-25

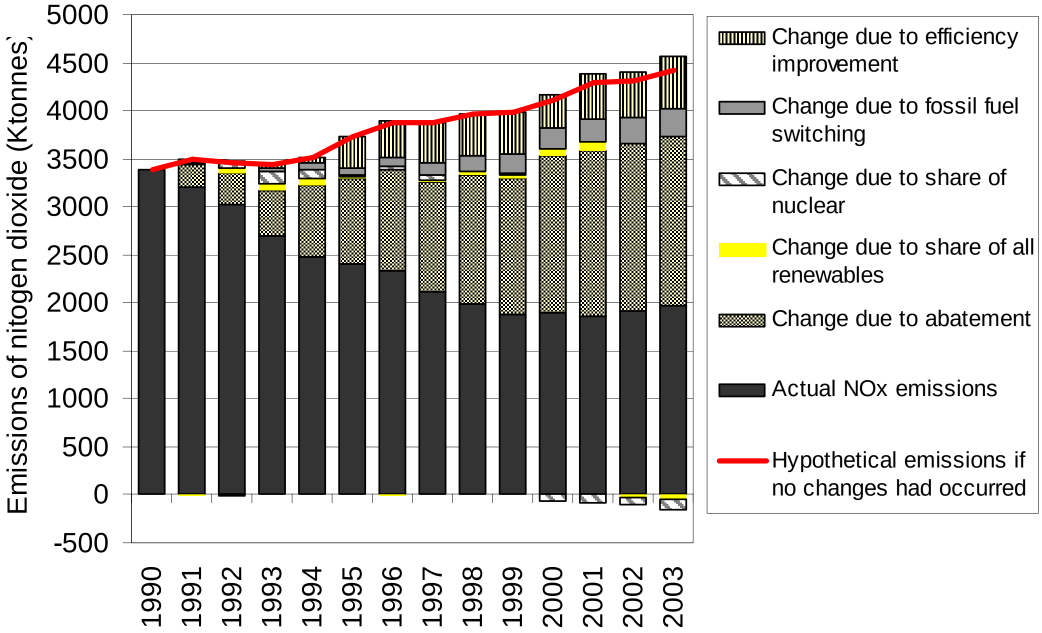
a) CO_2



b) SO_2



c) NO_x



Notes: The charts show the *estimated* contributions of the various factors that have affected emissions from public electricity and heat production. The top line represents the hypothetical development of emissions that would have occurred due to increasing electricity production between 1990 and 2003, if the structure of electricity and heat production had remained unchanged from 1990 (i.e. if the shares of input fuels used to produce electricity and heat had remained constant, the efficiency of electricity and heat production also stayed the same and no additional abatement technologies had been introduced). However, there were a number of changes to the structure of electricity and heat production that tended to reduce emissions and the contributions of each of these changes to reducing emissions are shown in each of the bars. The cumulative effect of all these changes was that emissions from electricity and heat production actually followed the trend shown by the black bars. This is a frequently used approach for portraying the primary driving forces of emissions. The explanatory factors should not be seen as fundamental factors in themselves nor should they be seen as independent from each other.

Sources: European Environment Agency/European Topic Centre on Air and Climate Change, Eurostat

1. Indicator assessment

Public electricity and heat production is the most important source of CO_2 emissions (around one-third of all CO_2 emissions) and is the largest and second largest source of SO_2 and NO_x emissions, respectively (the largest for the latter being transport). There are generally four ways of reducing the environmental pressures from producing a given output of electricity and heat, i.e. not accounting for a reduced demand:

1. Increasing the share of non-fossil fuels, as power production from renewable energy sources and nuclear produce no harmful emissions at the point of electricity production (with the exception of thermal renewables that involve combustion, such as certain types of biomass and wastes; and nuclear waste)[1].
2. Increasing the efficiency with which electricity and heat is produced from fossil fuels. Advances in engineering technology and operational procedure have all resulted in improved efficiencies (see EN19). The use of combined heat and power (see EN20) increases efficiencies dramatically as much of the heat produced is used to provide useful energy services at other points of the system
3. Changing the mix of fossil fuels used for electricity and heat production. Coal, lignite and oil all naturally contain significant amounts of carbon, sulphur, nitrogen, which react with oxygen during combustion to form the oxides that cause damage to the environment. Natural gas contains significantly less of these chemicals, thus a switch from coal or lignite to natural gas leads to an environmental improvement.
4. Introducing emissions abatement techniques
   - Flue gas desulphurisation (FGD) can be fitted to reduce SO_2 emissions from the flue gases. There are a wide variety of FGD techniques, of which the most common are wet scrubbers. Wet scrubbers work by using a slurry or solution to absorb SO_2 producing an initially wet by-product. Frequently, limestone is used as the sorbent, generating gypsum as a by-product. Other techniques include spray dry scrubbing and regenerative processes. Typically, FGD can achieve SO_2 removal of more than 90 %.
   - Combustion modification and flue gas treatment can be used to reduce NOx emissions. One of the most common forms of combustion modification is to use low NO_x burners. There are various types of low NO_x burner, which all reduce the formation of NO_x by controlling the mixing and proportions of fuel and air, and typically can reduce NO_x emissions by up to 40 %. Flue-gas treatment can also be used to remove NOx from the flue gases.[2]
   - Carbon Capture and Storage may also be option in the future for CO_2 emissions, but the technology has not yet entered the market.

As a result of these measures, the emissions of public power production were reduced between 1990 and 2003 despite a 30 % increase in the amount of electricity and heat produced.

a) CO_2 emissions:

Emissions of CO_2 from public electricity and heat production in the EU-25 decreased by 3.9 % between 1990 and 2003. However, if the structure of electricity and heat production had remained unchanged from 1990 (i.e. if the shares of input fuels used to produce electricity and heat had remained constant and the efficiency of electricity and heat production also stayed the same), then by 2003 emissions of CO_2 would have increased by 30 % above their 1990 levels, in line with the additional amount of electricity and heat produced. This means that the hypothetical emissions in 2003 would have been 33.9 % above the actual emissions (30 % avoided + 3.9 % actual reduction observed). The relationship between the increase in electricity generation and the actual reduction in emissions during 1990-2003 can be explained by the following factors:

- Improvements in the thermal efficiency of electricity and heat production of approximately 3 percentage points (see EN19) (e.g. from the closure of old, inefficient power plants and the introduction of new plants based on more efficient combined cycle technologies). During 1990-2003, there was a 13 % reduction in the fossil-fuel input per unit of electricity produced from fossil fuels.
- Changes in the fossil fuel mix used to produce electricity (e.g. fuel switching from coal and lignite to natural gas, see EN27), with much of this being linked to the increased use of the economically attractive gas turbine combined cycle

[1] The production of electricity from biomass, produces SO_2 and NO_x emissions, but is generally stated to have zero net CO_2 emissions. Therefore when considering emissions of CO_2, electricity generation from combustible renewables is also considered as part of non-fossil fuels. Nuclear power produces little pollution under normal operations, but there is a risk of accidental radioactive releases, and highly radioactive wastes are accumulating for which no generally acceptable disposal route has yet been established.

[2] Two of the most common types of flue gas treatment are selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR). SCR uses ammonia which is injected into the flue gas and passed over a catalytic bed. The ammonia reduces NOx to nitrogen and water — removal of up to 90 % can be achieved. In SNCR the flue gas is reduced without a catalyst, again often using ammonia. SNCR is less effective in removing NOx than SCR.

technology and the closure of a number of coal-fired power plants. However, a rise in the price of gas relative to coal in recent years has led to increased utilisation of existing coal plants, and is the primary cause of a rise in emissions from public electricity and heat production from around 1999 onwards (+ 1.1 %). There was a 17 % reduction in the CO_2 emissions per unit of fossil-fuel input during 1990-2003.

- The approximately 2 % lower share of nuclear and renewable energy (including biomass) in 2003 compared to 1990. During 1990-2003, the share of electricity from fossil fuels in total electricity production increased by 2 %. This effect has become more pronounced in recent years with a decrease in hydropower due to low rainfall (EN27).

These three factors interact with each other in a multiplicative way: Actual CO_2 emissions reduction = 1.3 (increase in electricity production) X 0.87 (efficiency improvement) X 0.83 (fossil fuel switching) X 1.02 (increase in nuclear and renewable share)[3] = 0.96. The combined effect was a reduction of 3.9 % in CO_2 emissions in 2003 compared to the 1990 level.

Linking the changes in CO_2 emissions to specific policies that have been targeted at public electricity and heat production is difficult. Furthermore, a number of the policy measures such as the Directive on renewable electricity (2001/77/EC), the EU Emissions Trading Scheme (2003/87/EC) and the Large Combustion Plant Directive (2001/80/EC) may have had a limited effect in the time series covered (1990-2003). More detailed analysis concerning total energy consumption has been undertaken for Germany and the UK (Fraunhofer Institute, 2001): that work suggests that around 60 % of the reductions in total energy-related CO_2 emissions in the two countries are the result of special circumstances (unification in Germany which led to the closure of many inefficient, coal-fired power plants and energy market liberalisation in the UK) rather than being directly attributable to the effects of climate-related policies. It is likely that an analysis specifically looking at public power production in the two countries would indicate similar conclusions. However, the impact of new policies, in particular the EU Emissions Trading Scheme, are likely to have a greater influence in the future.

b) SO_2 emissions:

Emissions of SO_2 from public electricity and heat production in the EU fell by 66 % over the period 1990 to 2003. As per CO_2 emissions, if the structure of power production had remained unchanged from 1990 then by 2003 emissions of SO_2 would have increased by 30 % above their 1990 levels, in line with the additional amount of electricity and heat produced. This decoupling of SO_2 emissions and electricity and heat production over the period 1990 to 2003 has been due to:

- The introduction of flue gas desulphurisation (FGD) and the use of lower sulphur coal and oil, which led to a 63 % reduction compared with 1990 levels.
- The switch in the fuel mix away from coal and oil towards lower sulphur fuels such as natural gas, which led to a 21 % reduction.
- Efficiency improvements, which resulted in a 12 % reduction.
- The 2 % lower share of nuclear and non-thermal renewable energy (i.e. excluding biomass) in 2003 compared to 1990, which actually increased emissions by 3 %[4].

In a similar manner to CO_2 emissions the overall multiplicative impact of these individual influencing factors was a 66 % reduction in SO_2 emissions in 2003 compared to 1990 levels. The increased utilisation of coal plants has in recent years meant that the decline in SO_2 emissions has slowed, although the significant specific reductions which can be achieved by flue gas desulphurisation means that SO_2 emissions have not risen in absolute terms.

c) NO_x emissions:

Emissions of NO_x from public electricity and heat production in the EU fell by 42 % over the period 1990 to 2003. If the structure of power production had remained unchanged from 1990 then by 2003 emissions of NO_x would have increased by 30 % above

(1) [3] The specific nuclear effect can be separated from the renewable effect in an additive way. These two factors will then be additive to each other and the combined renewable and nuclear effect will remain multiplicative to the already-mentioned fuel-switching and efficiency factors. About 99 % of the combined nuclear-renewable factor effect between 1990 and 2003 is accounted for by the nuclear factor alone.

(2) [4] For SO_2, biomass has been included in the share of fossil fuels, as the combustion of biomass leads to the emissions of SO_2 (for CO_2, the assumption is that emissions from biomass are neutral). Thus, the combined nuclear-renewables effect excludes biomass. As with CO_2, the individual components can be separated additively in a way that 68 % of the combined effect is explained by the nuclear component and the remainder by non-thermal renewables.

their 1990 levels, in line with the additional amount of electricity and heat produced. This decoupling of NO_x emissions and electricity and heat production over the period 1990 to 2003 has been due to:

- The introduction of low-NO_x combustion technology and flue gas treatment, which led to a 47 % reduction.
- Efficiency improvements, which resulted in a 12 % reduction.
- The switch in the fuel mix, away from coal and fuel oil towards natural gas, which led to a 7 % reduction.
- The lower share of nuclear and non-thermal renewable energy (i.e. excluding biomass) in 2003 compared to 1990, which actually increased emissions by 3 %[5].

The overall effect was a 42 % reduction in NOx emissions in 2003 compared to 1990 levels. The increase in NOx emissions in the period 2000 to 2003 is, in a similar manner to that for CO_2 emissions, linked to an increased use of coal and lignite for electricity and heat production from 1999/2000 onwards.

2. Indicator rationale

2.1 Environmental context

Public electricity and heat production contributes around one third of all CO_2 emissions and 27 % of all GHG emissions in the EU-25, thus contributing to global climate change. Carbon dioxide, along with other gases, reduces the earth's albedo, thus increasing the warming effect of the sun. This warming effect is thought to be responsible for rising sea levels and increasingly unpredictable weather patterns resulting in increased flooding and drought. These geophysical impacts are linked with reduced fertility of soils, reduced areas of fertile land, increased human and animal disease, increased damage to property and changes to the natural biodiversity.

Emissions of sulphur dioxide and nitrogen oxide cause acid deposition, which leads 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. Public electricity and heat production emits 54.3 % of all SO_2 emissions (energy and non-energy-related).

NOx is also a tropospheric ozone precursor, which reacts in the atmosphere in the presence of sunlight to from ozone. High levels of ozone can cause adverse impacts on health and can damage crops and other vegetation. Ozone is also a contributor to climate change. The sector contributes 18 % of all NOx emissions.

The indicator measures how the emissions of CO_2, SO_2 and NOx of public electricity and heat production developed over time and estimates how they would have developed if improvements in emissions abatement, generation efficiency and fuel switching had not taken place. It also tries to explain which factors influenced the emissions to what extent.

2.2 Policy context

Emissions of CO_2 from public electricity and heat production contribute significantly to total greenhouse gas emissions in the EU. The indicator estimates to what extent changes in efficiency, fuel mix and pollution abatement have influenced the reduction of emissions. These changes cannot directly be associated with the policies and measures introduced, but can provide an indication of their aggregate impact.

In line with European Community and Member States' commitments under the Kyoto Protocol of the United Nations Framework Convention on Climate Change, policies are being implemented in this sector to limit or reduce emissions. Policies and measures that will contribute to reducing CO_2 emissions from public electricity and heat production include those that aim to increase energy efficiency and to change the fuel mix in favour of fuels that emit less CO_2, for example, the Directive on renewable electricity (2001/77/EC) and the EU Emissions Trading Scheme (2003/87/EC), with the latter likely to favour a shift from carbon intensive coal generation towards natural gas generation.

Emissions of SO_2 and NO_x from public electricity and heat plants contribute significantly to acidification in the EU and are responsible for over 80 % of SO_2 and NO_x emissions from the energy supply sector. The large combustion plant Directive (2001/80/EC) plays an important role in reducing emissions of SO_2 and NO_x from combustion plants with a capacity greater

[5] For NOx, biomass has also been included in the share of fossil fuels. As with SO_2, the individual components, nuclear and non-thermal renewables, can be separated additively, with about 68 % of the combined effect explained by the nuclear component and the remainder by non-thermal renewables.

than 50 MW. The Directive sets emission limits for new plants and requires Member States to establish programmes for reducing total emissions. Emissions limits for all plants will be revised in 2007 under the integrated pollution prevention and control Directive (96/61/EC). The national emission ceilings Directive (2001/81/EC) sets targets for Member States for the reduction of SO_2 and NO_x emissions, as well as setting interim environmental objectives for reducing the exposure of ecosystems and human populations to damaging levels of acid pollutants.

Sulphur emissions from oil-fired electricity and heat production will also be limited by the Directive for the sulphur content of certain fuels (93/12/EC). The Directive requires Member States to cease the use of heavy fuel oil with a sulphur content greater than 1 % by mass from 2000, and the use of gas oil with a sulphur content greater than 0.2 % from 2000 and greater than 0.1 % from 2008.

References

Directive 96/61/EC concerning integrated pollution prevention and control

Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market.

Directive 2001/80/EC on the limitation of emissions of certain pollutants into the air from large combustion plants

Directive 2001/81/EC on national emission ceilings for certain atmospheric pollutants

Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC

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

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

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

Eurostat, New Cronos database.

Fraunhofer Institute, SPRU, DIW (2001) Greenhouse gas reductions in Germany and the UK - Coincidence or policy induced? An analysis for international climate policy. Report prepared for the Conference of the Parties (COP 6 bis), Bonn, Germany, July 16-27, 2001.

Meta data

Technical information

1. Data source:
   Historical emissions - European Environment Agency - European Topic Centre on Air and Climate change.
   Historical energy data – Eurostat http://europa.eu.int/comm/eurostat/

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.

3. Geographical coverage: EU25

4. Temporal coverage: 1990 to 2003

5. Methodology and frequency of data collection:
   CO_2 emissions data are annual official data submissions to the United Nations Framework Convention on Climate Change (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 Intergovernmental Panel on Climate Change (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 (United Nations Economic Commission for Europe) CLRTAP (Convention on Long-range Transboundary Air Pollution) and EMEP (Co-operative programme for monitoring and evaluation of the long range transmission of air pollutants in Europe). 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 datasets 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.
Average annual rate of growth calculated using: [(last year/base year) ^ (1/number of years) –1]*100.Average.
These indicators estimate the contribution that various changes in the EU public electricity and heat sector have on reducing harmful emissions. The changes that have been analysed are:

- the increase in the share of non-fossil fuels (increased electricity production from nuclear and (non-combustible) renewable sources);
- the increase in efficiency with which electricity and heat is produced from fossil fuels;
- the changing mix of fossil fuels used for electricity and heat production;
- the introduction of emissions abatement techniques (e.g. low NOx burners to control NOx emissions and flue gas desulphurisation or use of lower sulphur coals to control SO_2 emissions).

No direct quantitative information is available on the effect of abatement techniques, so the effect of these measures on SO_2 and NO_x emissions have been assumed to be equal to the residual effect, once the contribution of the other changes has been identified.
a) Reference emissions:
These are first calculated by assuming a constant structure of production in 1990 and that emissions in this base year then scale linearly with net electricity production (the sum of Eurostat New Cronos Database codes: Transformation output from public conventional thermal power plants (ktoe) 101121; Transformation output from nuclear power plants (ktoe) 101102; Electricity generation from hydro plants 5510 - 100900; Electricity generation from wind plants 5520 - 100900).

$$\text{Emission}_{\text{reference}}(\text{year}) = \text{total net production}(\text{year}) \times \frac{\text{Emission}(1990)}{\text{total net production}(1990)}$$

b) Emissions reduction due to the increased share of nuclear and renewable energy:
The share of fossil fuels is given by public production of electricity from thermal plants (101121) divided by total public production from all sources (transformation output of electricity and heat for conventional thermal and nuclear plant, plus gross production for renewables – i.e. the sum of all components in a) above). However, the production of electricity from public thermal plants (101121) is modified to account for the components of biomass and geothermal energy which should be subtracted as they are classed as renewable (note that for SO_2 and NO_x, the share of fossil fuels also includes biomass, as the combustion of biomass leads to the emissions of SO_2 and NO_x). For geothermal energy this is achieved by subtracting Gross electricity generation - Geothermal power plants (code 6000 – 107002) from the production of electricity from thermal plants (101121). For biomass an estimate is made of the gross electricity generation from biomass (6000 – 107011) from public thermal generation as opposed to all thermal generation by taking the ratio of the biomass inputs of the former to the latter (code (5500 – 101021 renewable energies input to public thermal power stations) divided by (5540 – 101001 biomass and wastes input to conventional thermal power stations)) and multiplying this by the gross electricity generation from biomass (6000 – 107002).

$$\text{Emission}_{\text{fossil}}(\text{year}) = \frac{\text{share of fossil fuel}(\text{year})}{\text{share of fossil fuel}(1990)} \times \text{Emission}_{\text{reference}}(\text{year})$$

The specific nuclear effect can be separated from the renewable effect in an additive way. These two factors will then be additive to each other and the combined renewable and nuclear effect will remain multiplicative to the fuel-switching and efficiency factors.
c) Emissions reduction due to fossil fuel switching:
Using emission factors from IIASA's RAINS model for each Member State, the relative contribution of coal, oil, gas and a few other fuels to 1990 EU emissions is estimated. Using the transformation input from conventional thermal energy by fuel data from New Cronos (Total fuel input to public conventional thermal power plants 101001 minus Renewable energy input to public conventional thermal electricity plants 5000 - 101021), implied 1990 emission factors for the use of these fuels are determined. From this the apparent or implied EU-25 emission factor for each year is calculated. The 1990 emission factors for EU-25 are the weighted averages over Europe.

$$\text{Emission}_{\text{fossil mix}}(\text{year}) = \sum_{\text{fuels}} \frac{\text{implied emission factor}_{\text{fuel}}(\text{year})}{\text{implied emission factor}_{\text{fuel}}(1990)} \times \text{Emission}_{\text{fossil}}(\text{year})$$

d) Emissions reduction due to efficiency improvements:
The emissions due to the change in fuel efficiencies (obtained from the transformation output (electricity and heat) from public fossil fuel

plants (101121) divided by transformation input to public fossil fuel plants (101001, but also subtracting code 5000 – 101021 to account for renewable energy input in the case of CO_2 emissions) were estimated by assuming that the emissions as calculated in the previous step decrease as efficiency increases:

$$Emission_{efficiency}(year) = \frac{Efficiency(1990)}{Efficiency(year)} \times Emission_{fossil\ mix}(year)$$

Note as in part b), for SO_2 and NO_x, the efficiency of fossil fuel plants also includes those using biomass as a fuel input (i.e. code 5000 – 101021 is not subtracted from 101001), as the combustion of biomass leads to the emissions of SO_2 and NO_x.

e) Reduction due to abatement technologies:
This reduction is assumed to be the residual difference between the reference emissions in a) and the factors that influence a reduction in emissions in b) to d).

Quality information

7. Strength and weaknesses (at data level):
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.
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.

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

Indicator uncertainty (historical data):
The indicator utilises a frequently used approach for portraying the primary driving forces of emissions, and it is based on the multiplicative *IPAT and KAYA identities.*
IPAT identity: Impact = Population × Affluence × Technology
KAYA identity: CO_2 Emissions = Population × (GDP/Population) × (Energy/GDP) × (CO_2 /Energy)
For the CO_2 explanatory factors the identity used is:
CO_2 emissions from electricity and heat production =
Total electricity and heat output
x electricity and heat fossil fuels/total electricity and heat output
x fossil fuel input/electricity and heat from fossil fuels
x CO_2 emissions from electricity and heat production/fossil fuel input.
The multiplicative identity is an accounting method since a factor could be estimated through the remaining factors by simple addition and subtraction. It is important to note that the components should not be seen as fundamental or completely independent from each other (i.e. existence of interaction). Despite of its limitations, the method provides a useful illustration of the importance of different factors in explaining changes in CO_2 emissions.
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 (2005). 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