EN19 Efficiency of conventional thermal electricity and heat production

Key message

The efficiency of both electricity, and combined electricity and heat production from conventional thermal power plants improved steadily between 1990 and 2005. This was due to the closure of old inefficient plants, improvements in existing technologies and the installation of new, more efficient technologies, often combined with a switch from coal power plants to more efficient combined cycle gas-turbines. This trend is expected to continue in the future. However, the rapid growth in fossil-fuel based electricity production outweighs some of the environmental benefits of the efficiency improvements.

Rationale

The majority of thermal generation is produced using fossil fuels with associated environmental impacts such as greenhouse gas emissions, but can also include biomass, wastes and geothermal. Whilst the level of environmental impact depends upon factors such as the particular type of fuel and the extent to which abatement technologies are used, all else being equal, the greater the efficiency the lower the environmental impact for each unit of electricity produced.

Fig. 1a: Efficiency (electricity and heat) production from conventional thermal plants, 1990 and 2005

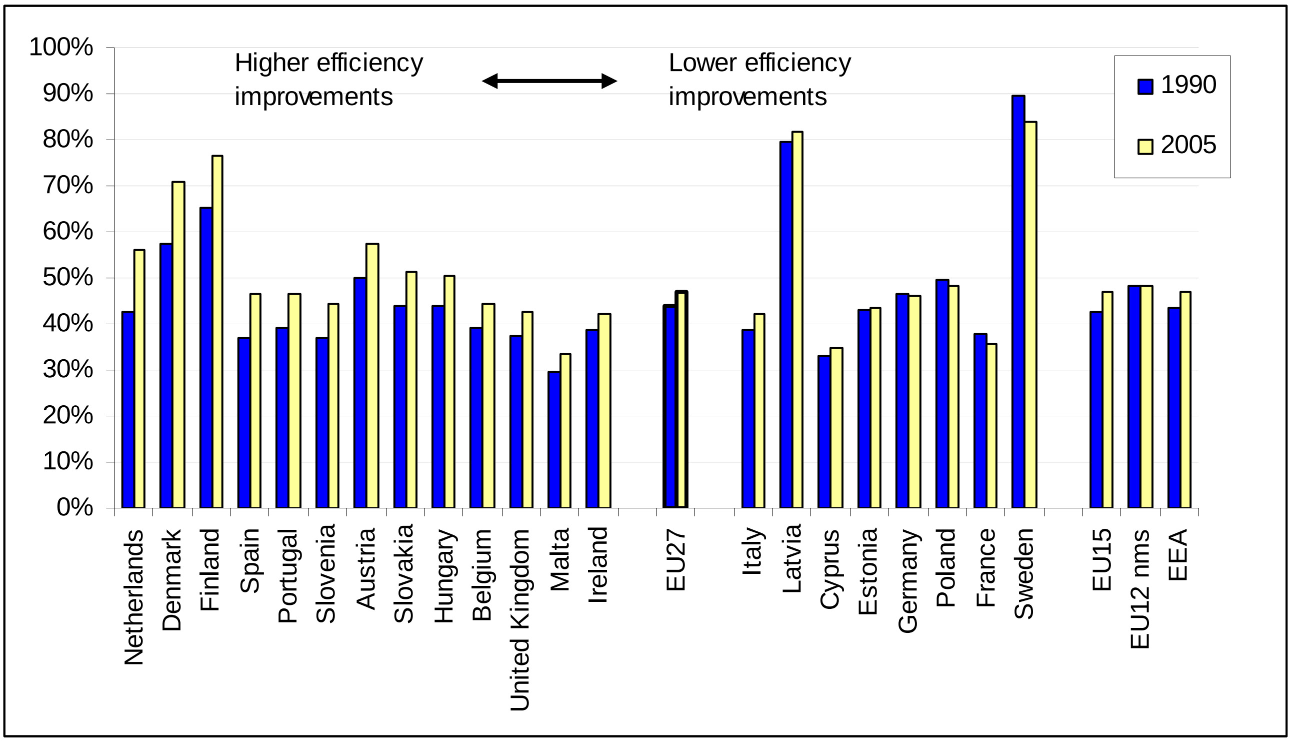


Fig. 1b: Efficiency (electricity and heat) from public conventional thermal plants, 1990 and 2005

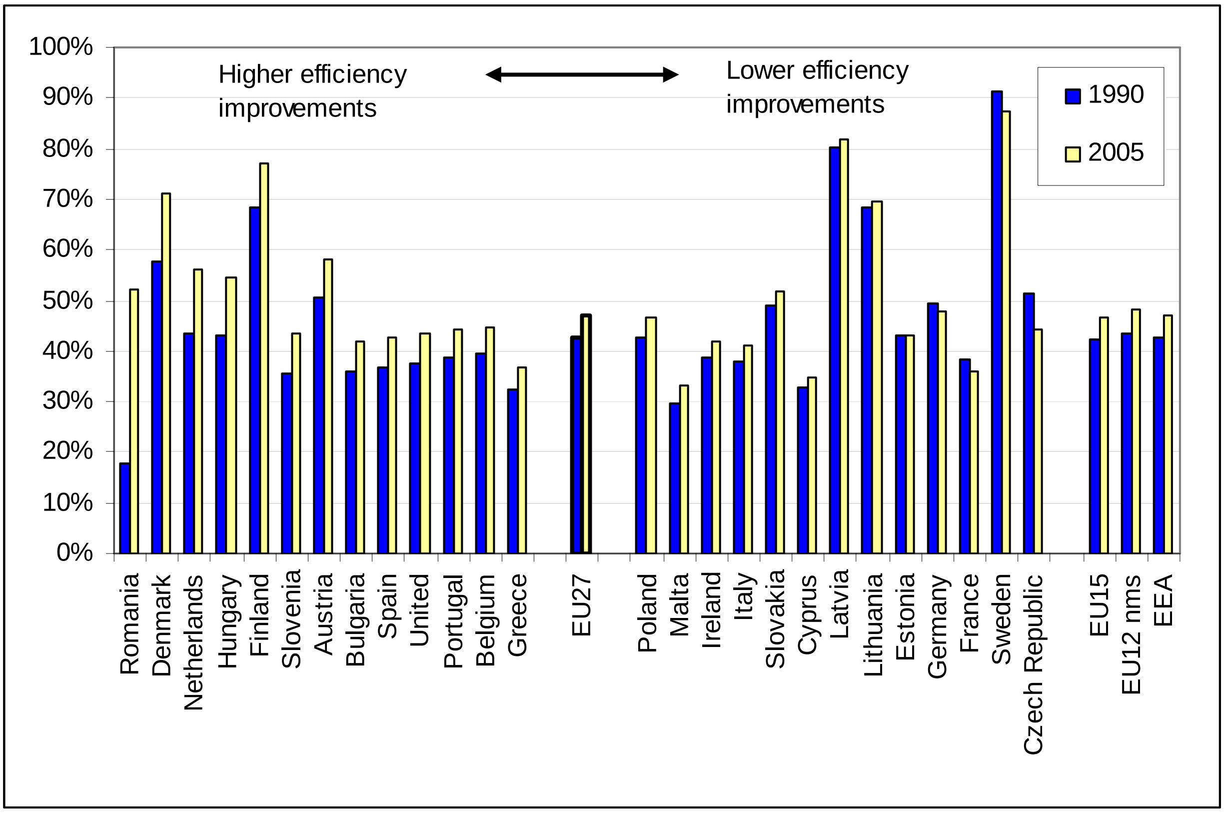
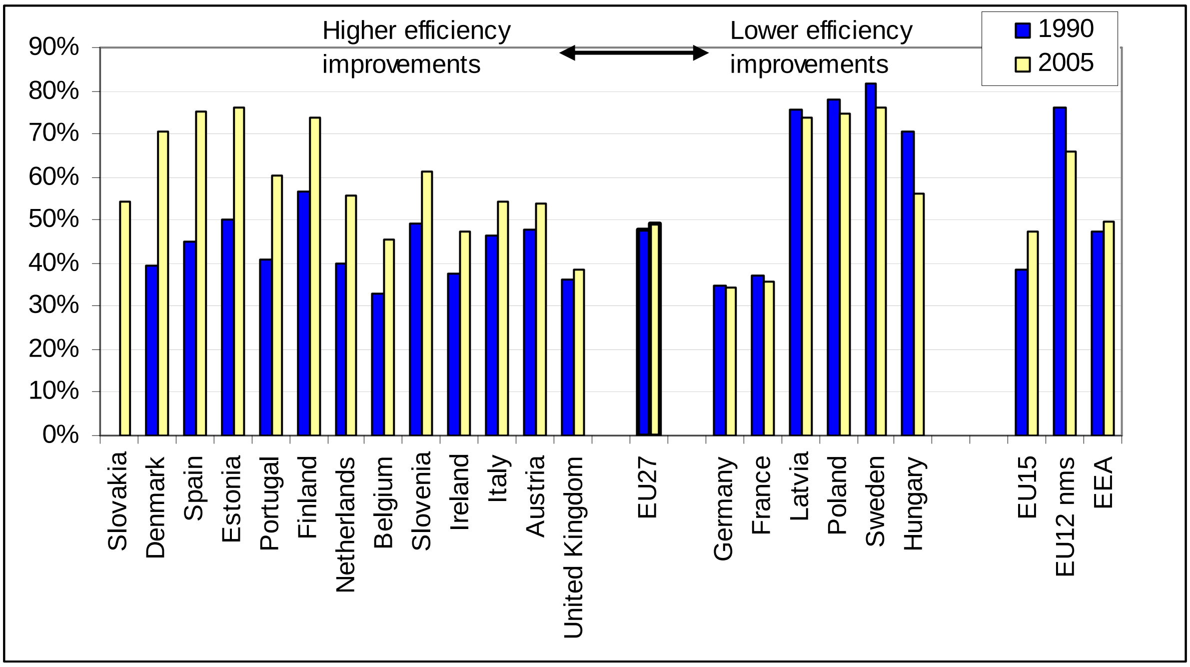


Fig. 1c: Efficiency (electricity and heat) from autoproducers conventional thermal plants, 1990 and 2005



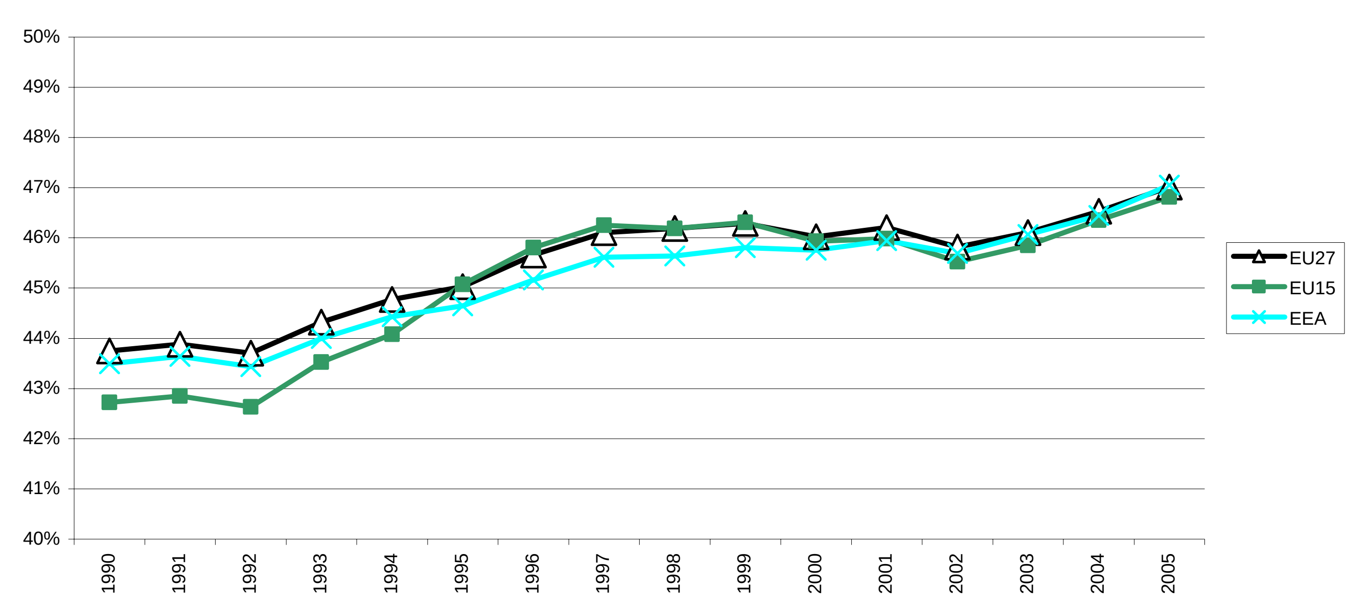
Data source for Figures 1a, 1b and 1c: Eurostat

Notes: Output from conventional thermal power stations consists of gross electricity generation and also of any heat sold to third parties (combined heat and power plants) by conventional thermal public utility power stations as well as autoproducer thermal power stations.

Notes 1a & 1b: Due to inconsistencies in the Eurostat data set regarding public production in Luxembourg (input data is registered, output data is zero in 1990) and Norway (efficiencies >100%), this data is excluded from the figure and in total efficiency, but only for 1990.

Notes 1a & 1c: Due to inconsistencies in the Eurostat data set regarding autoproducers production in Bulgaria, Greece, Romania, Luxembourg and Lithuania (efficiencies >100%) and Czech Republic (input data is zero, output is registered), the data of these countries are excluded. For Cyprus and Malta data on autoproducers is not available. Norway is completely excluded due to unreliable data.

Fig. 2: Efficiency of conventional thermal electricity and heat production



Data source: Eurostat
Notes: see above

1. Indicator assessment

The indicator shows the efficiency of electricity and heat production from conventional thermal plants. A distinction is made between public (i.e. main activity producers) thermal plants and autoproducers. Public thermal plants mainly produce electricity (and heat) for public use. Autoproducers produce electricity (and heat) for private use, for instance in industrial processes. The efficiency of electricity and heat production is an important factor since losses at production account for a substantial part of the primary energy consumption. Higher efficiency of production therefore results in substantial reductions in primary energy consumption.

In the “Energy Policy for Europe” (COM(2007)2) and the “Action Plan for Energy Efficiency” (COM(2006)545), the European Commission sets targets for a 20% reduction of energy-use in Europe in 2020. One of the priority actions (#3) of the Action Plan focuses on more efficiency in power generation. Following this action the Commission will by 2008 develop minimum efficiency requirements for new electricity, heating and cooling capacity lower than 20 MW. Furthermore it considers such requirements for larger units.

The average energy efficiency of conventional thermal electricity and heat production in the EU-27 improved over the period 1990-2005 by 3.3 percentage points to 47.0 %. For most countries efficiency improved, but for three countries there was a net decrease in efficiency (Poland, France and Sweden). The decrease of efficiency in these countries is not part of a continuing trend, but due to annual fluctuations.

For public thermal power plants the average efficiency increased in most countries over the period 1990- 2005, resulting in a net efficiency of 46.6% by 2005. For autoproducers the average efficiency also increased in most countries over the period 1990-2005, resulting in a net efficiency of 49.1% by 2005. The higher efficiency for autoproducers is largely explained by the fact that the installations of autoproducers are often designed or dimensioned more suitable for the electricity and heat demand on a location.

For both public thermal plants and autoproducers, this energy efficiency improvement has been due to a combination of factors including the closure of old inefficient plants, improvements in existing technologies, installation of new, more efficient technologies, often combined with a switch to fuels with a better generating efficiency, such as from coal power plants to high-efficiency combined cycle gas-turbines. Environmental regulation has also been important in encouraging improvements and fuel switching towards more efficient fuels. However, the main factor in the choice of new electricity production plant during the period 1990-2005 was economic, as the costs of electricity produced from gas-fired plants have generally been less than for coal or oil fired plants, which has led to gas being the more desirable fuel for new plants.

The growth in the use of combined cycle gas turbine plants (CCGT) has been an important factor in the improving efficiency seen in the pre-2004 EU-15 Member States. CCGT plants can achieve conversion efficiencies in the order of 60%, with the prospect of even higher efficiencies in future plants. However, continued improvements have also been made in conventional coal generation with plant capable of efficiencies in the range 40-45%, and further advances that may allow this to exceed 50% (IEA, 2005).

CHP provides a large potential for increasing efficiency of electricity-production and reduction of emissions of CO_2. Meeting the indicative EU-15 target of doubling the share of CHP in gross electricity production from 1994 to 2010 could lead to avoided CO_2 emissions of over 65 Mt CO_2/year by 2010. The potential at refineries in the Dutch port or Rotterdam equals app. 5 Mt CO_2/year (see EN20).

Although overall improvements in electricity generation efficiency have been seen over the period 1990 to 2005, a marginal stagnation in the late 1990s and a decline in efficiency has been observed in 2002. This has been due primarily to an increased utilisation of existing lower efficiency coal plant (see EN-27 for more details). In the following years the efficiency increased due to an increasing share of gas.

It should also be noted that positive impacts on the environment overall, due to reduced emissions, from increased efficiency in electricity production may be offset by the high rate of increase in electricity consumption, which is growing at an average rate of 1.7 % per year (see EN18), especially considering that over half of this electricity (53.6 % in 2005) is produced from coal, gas and oil (see EN27)[1]. There is also a potential tension between environmental legislation (for example the Large Combustion Plant Directive 2001/80/EC) requiring the reduction of other air pollutants such as SO_2, whereby retrofitting flue-gas desulphurisation technology incurs an energy penalty thus reducing overall efficiency. However, future coal technologies such as IGCC (Integrated Gasification Combined Cycle) can operate at higher efficiencies and also allow the sulphur, nitrogen compounds and particles to be removed prior to combustion (OECD, 2005).

At the beginning of the 1990s, the electricity sectors of the new EU Member States were characterised by low efficiencies of production mainly due to obsolete plant technology. However, in the second half of the 1990s investments were made to improve the performance of existing plants. Another significant trend was a switch from coal to gas in new and reconstructed fossil fuelled heat and power plants. This also contributed to an increase in generating efficiency due to the higher efficiency of gas combined cycle technologies. The growth in the use of gas has been supported by environmental regulation, government support (as high-efficiency electricity production from gas is seen as a low-pollution option) and programmes to finance enlargement of the gas networks.

The greatest efficiency improvements in both electricity and electricity and heat production occurred in Luxembourg (construction of a new CCGT) and in Cyprus (new more efficient plant). Significant decreases in the efficiency of electricity production were seen in the Czech Republic between 1990 and 2005, but closer examination of the trend shows a sharp fall in efficiencies in the early 1990s during the period of economic collapse due to low utilisation of plants, followed by relatively constant efficiencies in more recent years.

Efficiencies of fossil-fired electricity and heat production in different countries have been compared in a recent study (Ecofys, 2007). It appears that efficiencies in European countries (France, UK, Ireland, Nordic countries and Germany) are higher than the world-wide average. When the worldwide average is set at 100%, efficiencies in India and China are typically 15 – 19 % lower than those in the investigated European countries. The efficiencies in the USA are 1% below the average level.

The trend in increasing efficiency is expected to continue into the future, as new more efficient technologies are introduced, in particular with the increased market penetration of combined cycle gas turbine technologies, and following the closure of older less efficient plants.

2. Indicator rationale

2.1 Environmental context

Changes in the efficiency of electricity production from conventional thermal power production provides an indication of their environmental impact, as the majority of fuel used for thermal generation uses fossil fuels with their associated environmental impacts such as greenhouse gas emissions and the release of other pollutants such as NO_x, SO_2 and particles. However, the overall environmental impact has to be seen in the context of the type of fuel (see EN27) and the extent to which abatement technologies are used (see EN06). All else being equal, the greater the efficiency of thermal power generation the lower the environmental impacts for each unit of electricity produced, as less input fuel is required to produce it.

2.2 Policy context

The EU Action Plan for Energy Efficiency (SEC(2006)1173, 1174 and 1175)) aims at boosting the cost-effective and efficient use of energy in the EU. It sets a target of 20% reduction of energy-use by 2020, compared to the baseline-projections. This

[1] Specific details of emission levels from electricity generating plants can be obtained for a variety of pollutants at the European Pollutant Emission Register.

target is also part of the EU Energy Policy for Europe (COM(2007)2). One of the priority actions is more efficiency in power generation. By 2008 the Commission will develop minimum efficiency requirements for new electricity, heating and cooling capacity lower than 20 MW. Furthermore it considers such requirements for larger units. It will also develop guidelines on good operating practices for existing capacity and for transmission and distribution. Furthermore, the Commission is working to promote the use of Combined Heat and Power (CHP, indicator EN20), in the framework of the Directive on the Promotion of Cogeneration (2004/8/EC).

The reduction of electricity consumption is seen in the context of reaching the target of an 8 % reduction in greenhouse gas emissions (the power generation sector was responsible for about 28 % of EU-15 emissions in 2005) by 2008-2012 from 1990 levels for the EU-15 and individual targets for most new Member-States, as agreed in 1997 under the Kyoto Protocol of the United Nations Framework Convention on Climate Change, as well as reaching the target of 20 – 30% reduction of emissions by 2020 as defined in the EU Energy Policy.

On January 23rd 2008 the European Commission presented a new package of legislative proposals regarding energy use and climate change. These include an improvement of the EU Emissions Trading Scheme (with a binding target of 21% emission reduction in 2020 vs. 2005). As all thermal electricity generating plants greater than 20 MW are part of the EU ETS, the caps on emissions in the EU-ETS will probably result in a drive towards higher efficiencies of power generation (European Commission, 2008).

The Action Plan for Energy Efficiency followed the Green Paper on energy efficiency (COM(2005)265 final) which highlighted the importance of improving the efficiency of thermal generation as the expected increase in demand for electricity is likely to require over 500GW of new capacity to be installed up to 2030. The paper specifies the need to ensure that: the most efficient CCGT technology is used; research is expanded to improve the efficiency of coal generation; the use of distributed generation is expanded particularly to make greater use of waste heat, and that in combination with this a greater use of combined heat and power (cogeneration) technology is realised.

A number of EU policies have also had an impact on the changes in the efficiency of electricity and heat production. For example, the Directives concerning common rules for the internal market in electricity (2003/54/EC) and gas (2003/55/EC) have led to the progressive introduction of competition in the electricity supply industry. It is expected that these new market structures will encourage switching to cheaper and more efficient technologies.

Other relevant policies include: the Directive on the promotion of high-efficiency cogeneration (2004/8/EC); the Large Combustion Plant Directive (2001/80/EC) which aims to control emissions of SO_x, NO_x and particulate matter from large (>50MW) combustion plants and hence favours the use of higher efficiency CCGT as opposed to coal plants; the IPPC Directive (96/61/EC) which requires plant of <20MW to meet a set of basic energy efficiency provisions.

References

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COM(2008) 16 Proposal for a Directive amending Directive 2003/87/EC (EU ETS)

COM(2008) 17 Proposal for a Decision on the effort of Member States to reduce their greenhouse gas emissions

Council Decision 2002/358/EC to ratify the Kyoto Protocol under the United Nations Framework Convention on Climate Change

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

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

Directive 2003/55/EC concerning common rules for the internal market in natural gas and repealing Directive 98/30/EC

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

Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market amending Directive 92/42/EEC.

Ecofys (2007), International comparison of fossil power efficiency, Ecofys, august 2007

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Meta data

Technical information

1. Data source:
   Fuel input to, and electricity and heat output from conventional thermal power stations: Eurostat (historical data) http://europa.eu.int/comm/eurostat/.

2. Description of data/Indicator definition:
   Output from conventional thermal power stations consists of gross electricity generation and also of any heat sold to third parties (combined heat and power plants) by conventional thermal public utility power stations as well as autoproducer thermal power stations. The energy efficiency of conventional thermal electricity production (which includes both public plants and autoproducers) is defined as the ratio of electricity and heat production to the energy input as a fuel. Fuels include solid fuels (i.e. coal, lignite and equivalents, oil and other liquid hydrocarbons, gas, thermal renewables (industrial and municipal waste, wood waste, biogas and geothermal energy) and other non-renewable waste.
   Units: Fuel input and electrical and heat output are measured in thousand tonnes of oil equivalent (ktoe)
   Efficiency is measured as the ratio of fuel output to input (%)

3. Geographical coverage:
   The Agency had 32 member countries at the time of writing of this fact sheet. These are the 27 European Union Member States and Turkey, Iceland, Norway, Liechtenstein and Switzerland.
   No energy data are available for Switzerland. No autoproducers data for Cyprus and Malta. Norway is excluded in the total and public data as the data was considered unreliable, giving efficiencies ≥ 100%. Bulgaria, Greece, Romania and Lithuania are excluded in the total and autoproducers data as they were considered unreliable, giving efficiencies ≥ 100%. Czech Republic is excluded in the total and autoproducers data as the data was considered unreliable, giving an output while there was no input. Luxembourg is excluded in all figures because the data was considered unreliable, giving efficiencies ≥ 100% (autoproducers) and giving zero output while input is given (public).

4. Temporal coverage: 1990-2005.

5. Methodology and frequency of data collection:
   Data collected annually.
   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:
   Average annual rate of growth calculated using: [(last year / base year) ^ (1/number of years) –1]*100
   Efficiency of electricity and heat production = (electrical output + heat output)/fuel input
   The coding (used in the Eurostat New Cronos database) and specific components of the indicator are:
   Numerator:
   a) Electricity output from conventional thermal power stations 101101 (6000 electrical energy) + Heat output from conventional thermal power stations 101101 (5200 derived heat)
   b) Electricity output from public thermal power stations 101121 (6000 electrical energy) + Heat output from public thermal power stations 101121 (5200 derived heat)
   c) Electricity output from autoproducer thermal power station 101122 (6000 electrical energy) + Heat output from autoproducer thermal power station 101122 (5200 derived heat)
   Denominator:
   a) Input to conventional thermal power stations 101001 (0000 all products)
   b) Input to public thermal power stations 101021 (0000 all products)
   c) Input to autoproducer thermal power stations 101022 (0000 all products)

Qualitative information

7. Strengths and weaknesses (at data level)
   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 efficiency of electricity production is calculated as the ratio of electricity output to the total fuel input. However, the input to conventional thermal power plants cannot be disaggregated into separate input for heat and input for electricity production. Therefore the efficiency rate of electricity and heat production equals the ratio of both electricity and heat production to fuel input, which assumes there is an efficiency rate for heat production.
Also, electricity data (unlike that for overall energy consumption) for 1990 refers to the western part of Germany only, so there is a break in the series from 1990-1992.
There are also slight differences in the calculation of efficiencies between the historical and projected data. In contrast to the Eurostat data, the projections take into account non-marketed steam, i.e. steam generated - either in boilers or in CHP plants - and used on site by industrial consumers. The calculation of projected efficiencies therefore takes into account both the non-marketed steam generated in CHP units as well as the corresponding fuel input whereas the calculation of historical efficiencies excludes both these components.

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