EN35 External costs of electricity production

Key message

The external costs that arise from the environmental impact of electricity production are significant in most EU countries and reflect the dominance of fossil fuels in the generation mix. In 2005 the average external costs of electricity production in the EU were between 1.8–5.9 Eurocent/kWh. Despite progress, these external costs are still not adequately reflected in energy prices. Consumers, producers and decision makers do not therefore get the accurate price signals that are necessary to reach decisions about how best to use resources.

Rationale

Electricity production causes substantial environmental and human health damages, which vary widely depending on how and where the electricity is generated. The damages caused are, for the most part, not integrated into the current pricing system and so represent external costs. The objective of the indicator is to assess the external costs associated with electricity production. When combined with information on environmental taxes and economic instruments, the indicator is relevant in assessing progress towards internalising external costs or 'getting the prices right'.

Fig. 1a: External costs of electricity production in the EU, 1990 and 2005 - low estimate

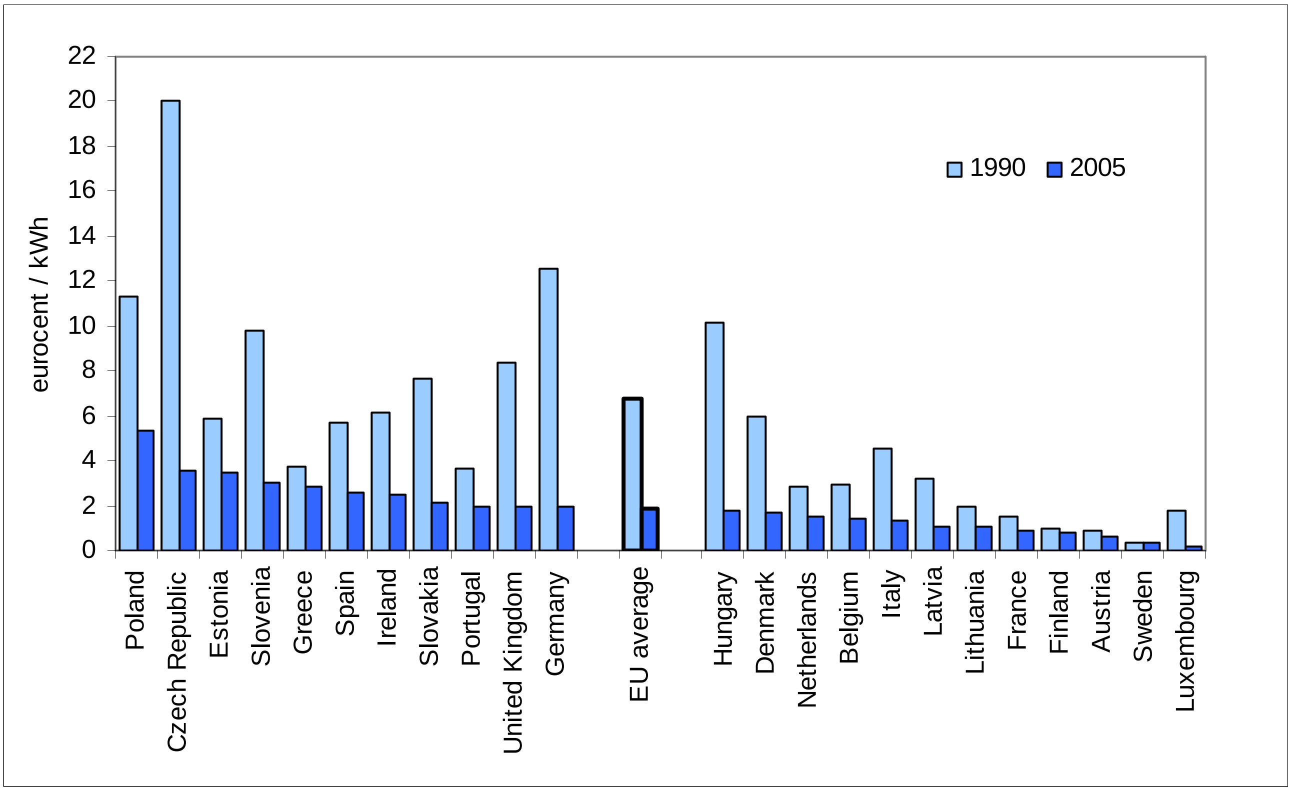
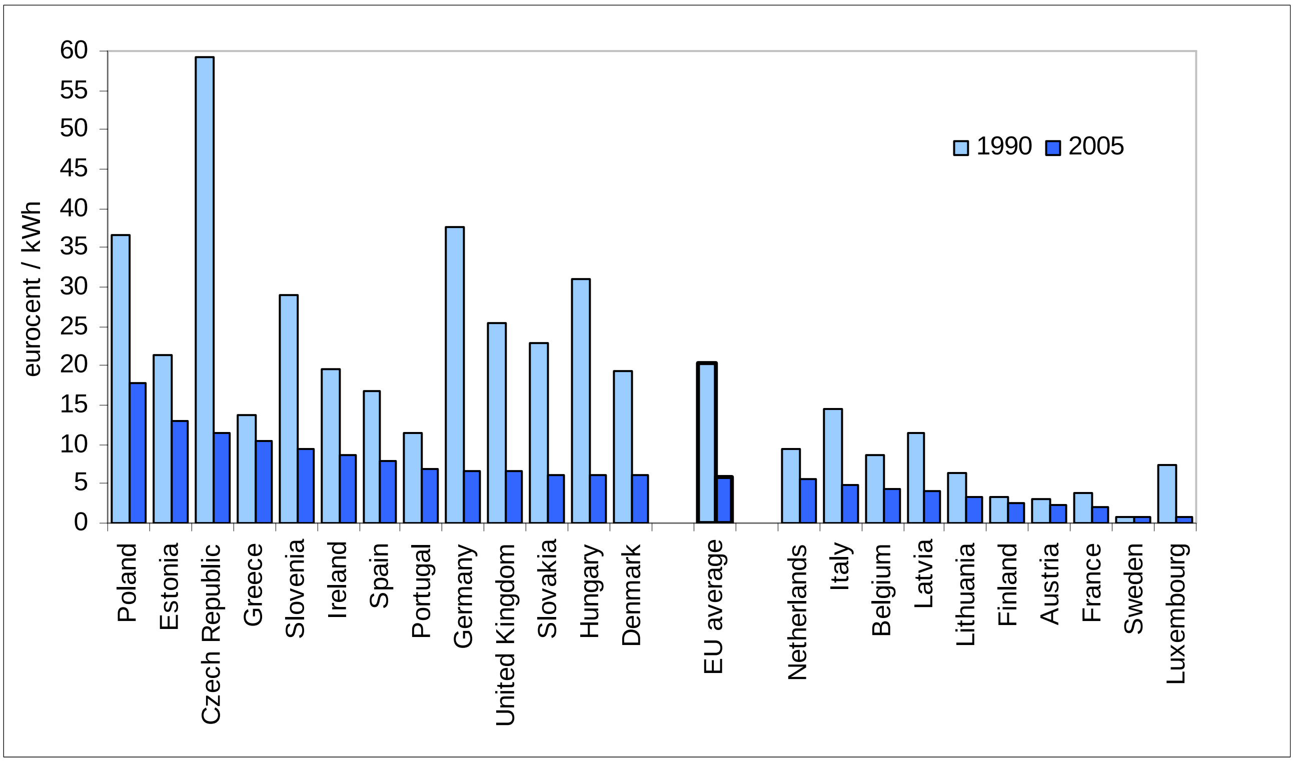


Fig. 1b: External costs of electricity production in the EU, 1990 and 2005 - high estimate



Data source: ExternE-Pol (2005), CAFE, EEA, Eurostat, RECaBS (2007)

Note: The external costs in the above two figures are based upon the sum of three components associated with the production of electricity: climate change damage costs associated with emissions of CO_2; damage costs (such as impacts on health, crops etc) associated with other air pollutants (NOx, SO_2, NMVOCs, PM_{10}, NH_3), and other non-environmental social costs for non-fossil electricity-generating technologies.

The external costs from nuclear have to be treated with caution, as only parts of the externalities are included (related to radioactive emissions from mine-tailings and possible nuclear accidents). The costs reflect to a large extent the small amount of emissions of CO2 and air pollutants, and the low risk of accidents. New estimates of the damage cost factors for nuclear energy are clearly needed in future ExternE projects (see note to figure 2 for more information).

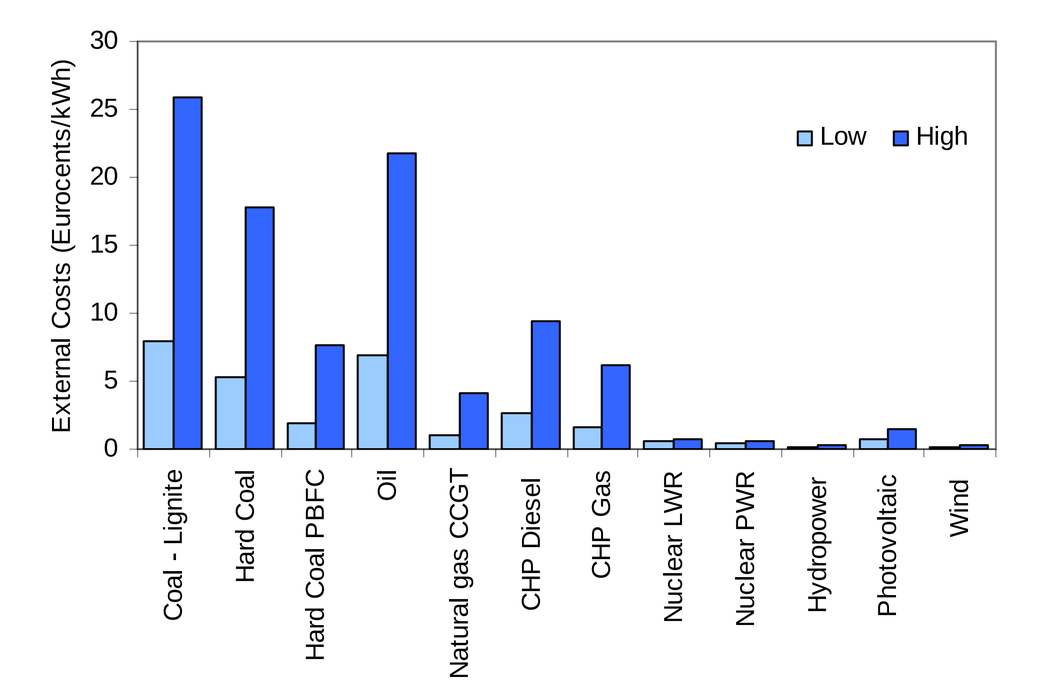
Marginal damage cost factors (cost in € per tonne of pollutant) are taken from ExternE-Pol (2005) in the case of CO_2 (low estimate) and from CAFE (Clean Air for Europe programme) in the case of the other air pollutants. The damage factors for CO_2 (high estimate) are taken from Watkiss et al. (2005). Marginal damage cost factors in the case of CO2 are not country specific (i.e. all countries share the same marginal factors for CO2, one for low, 19 Euro/tonne and one for high 80 Euro/tonne). Marginal damage cost factors in the case of other pollutants are country specific. For the low estimate, the low damage factors are then applied to the level of emissions by pollutant in each Member State in 1990 and 2005 to produce a damage cost in million Euro for each pollutant for each year. Summing up the damage costs of each pollutant gives the total damage costs in each Member State for each year. The same procedure is repeated to calculate the high estimate.

A complete data set for all emission types in this category is not available for Malta, Cyprus, Bulgaria and Romania so these countries have been excluded from the above graphs. Cyprus has been omitted due to the CAFE conclusion that marginal damage cost factors as a result of modelling work, for this country, were not considered sufficiently robust for inclusion in the final report.

The other non-environmental social costs for nuclear and non-thermal renewables are taken from ExternE-Pol (2005) with an estimate of the external cost of nuclear accidents (of 0.25 eurocent / kWh) taken from RECaBS (2007). These provide a eurocent/kWh external cost for different types of electricity technologies, which are multiplied by the quantity of electricity produced from each of these technologies, in each Member State, for 1990 and 2005 to produce a damage cost for that year in million euro. This cost is added to that associated with the emissions of CO_2 and other air pollutants and the total is then divided by the overall electricity production for that year in each Member State to produce an estimate (low and high) of the external costs associated with each unit of electricity generation.

Differences between the low and high estimate are mainly due to different methods of valuating changes in longevity. For further details on differences between ExternE-Pol and CAFE and between the CAFE low and high estimates see metadata section.

Figure 2: Estimated average EU external costs for electricity generation technologies in 2005



Data source: ExternE-Pol (2005), CAFE, EEA, Eurostat, RECaBS (2007)

Note: PBFC = pressurised fluidised bed combustion, CHP = combined heat and power, CCGT = combined cycle gas turbine, LWR = light water reactor, PWR = pressurised water reactor.

To calculate the external costs (Eurocents/Kwh) for the EU for each fuel/technology the following data were needed: 1) pollutant-specific emissions, for the EU, from each fuel/technology used for electricity production (from ExternE-Pol). Average emissions per unit of electricity generation include emissions from the operation of the power plant and the rest of the energy chain; 2) pollutant-specific (SO2, NOX, NMVOCs and PM2.5), EU-average (based on country-specific values), damage cost factors (high and low from CAFE); 3) pollutant specific, common to all countries, non-environmental social costs for non-fossil fuels (from ExternE-Pol and RECaBS for nuclear accidents); 4) ExternE-Pol damage cost factors for CO2, common to all countries (low, from ExternE-Pol and high, from Watkiss et al. (2005). Damage cost factors are not fuel specific but pollutant specific (e.g. the same SO2 factor applies to all fuels, lignite, hard coal etc). The external-costs estimate for a particular pollutant is different depending on the fuel because of different average emissions per kWh.

The external costs from nuclear have to be treated with caution, as only parts of the externalities are included. The costs reflect to a large extent the small amount of emissions of CO2 and air pollutants, radioactive emissions (primarily from downstream radioactive emissions from mine tailings along with a minor portion from operation of the plant itself). A key issue is related to the treatment of potential damage from nuclear accidents:

- In 2005, ExternE “Externalities of Energy”, Methodology 2005 Update http://www.externe.info/brussels/methup05a.pdf concluded that radiological impacts from emissions during power plant operation and final disposal were found to be only of minor importance for the overall results from the nuclear fuel cycle. In fact, the methodology to evaluate impacts due to accidents was risk-based (risk, being defined as the probability of accident multiplied by the consequences resulting from that accident). The report states that “it is sometimes argued that, for so-called Damocles risks, i.e. risks with a very high damage and a low probability, the risk assessment of the public is not proportional to the risk. The occurrence of a very high damage should be avoided, even if the costs for the avoidance are much higher than the expectation value of the damage. However past attempts to quantify this effect have not been successful or accepted, so there is currently no accepted method on how to include risk aversion in such an analysis. Consequently it is currently not taken into account within the ExternE methodology. Research on how to assess this, for example with participatory approaches, is clearly needed”.
    - No external costs for nuclear accidents are included in the estimates from ExternE-Pol (2005) due to the complexities in estimating this, however, By only considering its low air pollutant and CO_2 emissions, and the level of non-accident related radioactivity, the external costs are considerably lower than fossil fuel generation, and broadly on a par with renewables.
- By contrast the RECaBs (2007) estimate used in this indicator (in addition to the other non-environmental social costs for nuclear from ExternE-Pol) is based on earlier analysis which, broadly speaking, takes historic data on nuclear accidents more directly into the assessment of the probability of a future accident occurring (e.g. Chernobyl and Three Mile Island) and its cost (primarily from data on Chernobyl). Whilst this gives a much higher probability, and by extension a higher external damage cost, the estimate is still highly uncertain for a number of reasons (as outlined in the RECaBS supporting documentation). For example:
    - It may overestimate the probability of an accident occurring in a new state-of the art nuclear plant in Western Europe due to the fact that: serious deficiencies have been identified in the former USSR PWR design[1]; there was a lack of a regulatory body in the former USSR and safety culture was problematic.

(1) Although a precondition for EU Accession in a number of countries was that these reactors would be shut down

- Alternatively it may underestimate the external cost due to: higher population densities (and hence impacts) in many Western European Countries; higher GDP – and hence greater economic consequences; increased threats of terrorism.

RECaBS states that the estimate of 0.25 Eurocents/kWh also takes into account that future plants are assumed to be considerably safer than existing plants and that public anxiety about nuclear power is assigned an economic value.

1. Indicator assessment

The external costs used to calculate this indicator are based upon the sum of three components: climate change damage costs associated with emissions of CO_2; damage costs (such as impacts on health, crops etc) associated with other air pollutants (NO_x, SO_2, NMVOCs, PM10, NH_3), and other non-environmental social costs for non-fossil electricity-generating technologies. Based on the methodology used in this fact sheet (see e.g. note to figure 1 and metadata section), the external costs of electricity production have fallen considerably between 1990 and 2005 in almost all Member States, despite rising electricity production. However, the average external costs still represented between 1.8–5.9 Eurocent/kWh in the EU in 2005. These costs are significant and reflect the continued dominance of fossil fuels in the generation mix.

External costs for electricity are those that are not reflected in its price, but which society as a whole must bear. For example, damage to human health is caused by emissions of particulate matter (including both primary particles and secondary aerosols). SO_2, NO_X and VOC emissions also lead to human health impacts (which are considered to be the largest externality) through the formation of secondary pollutants. NO_X and VOC emissions have health impacts through the formation of ozone. SO_2 and NO_x emissions form secondary particles in the atmosphere (which have similar effects to primary PM). There are also costs associated with non-health impacts. SO_2 is the main pollutant of concern for building-related damage, though ozone also does affect certain materials. The secondary pollutants formed from SO_2, NO_X and VOC also impact on crops and terrestrial and aquatic ecosystems.

Damages from climate change, associated with the high emissions of greenhouse gases from fossil fuel based power production, also have considerable costs. However, given the long-time scales involved, and the lack of consensus on future impacts of climate change itself, there is considerable uncertainty attached to the damage costs. The uncertainty in the costs of climate change (external costs) concerns not only the 'true' value of impacts that are covered by the models, but also the uncertainty about the impacts that have not yet been quantified and valued. Moreover, none of the current estimates of the external costs include all the effects of climate change.

The external costs of CO_2 emissions must thus be interpreted with care. Watkiss et al (2005) stress that there is no single value and that the range of uncertainty around any value depends on ethical as well as economic assumptions. The damage factors for CO_2 used in this factsheet range from 19 EUR/t CO_2 (low estimate, based on ExternE-Pol) and 80 EUR/t CO_2 (high estimate, based on Watkiss et al., 2005). These two values are common to all countries.

The overall level of these externalities will depend upon a number of factors including:

- the fuel mix for electricity generation (e.g. the use of coal releases far more CO_2 and air pollutants than gas);
- the efficiency of electricity production (as the higher this is the less input fuel, and hence output emissions, are required to produce each unit of electricity);
- the use of pollution abatement technology, and;
- the location of the plant itself with respect to population centres, agricultural land, etc.

Environmental and social externalities are highly site specific and so results will vary widely even within a given country according to the geographic location. Results from the CAFE (Clean Air for Europe Programme) have highlighted that the highest damages are found from emissions in the central parts of Europe and the lowest from countries around the borders of Europe. This reflects variation in exposure of people and crops to the pollutants of interest – emissions at the borders of Europe will affect fewer people than emissions at the centre of Europe, due to the degree of urbanisation and population density. In addition, the analysis did not account for non-European bordering countries.

Traditional fossil systems (coal, oil and to a lesser extent natural gas) exhibit the highest external costs for electricity generating technologies, in the range of 1.1 Eurocent/kWh (for advanced gas technologies using the lower bound estimate of damage costs Eurocent/kWh) to 25.9 Eurocent/kWh (for traditional coal-lignite plants using the higher bound estimate of damage costs). These fuels accounted for about 54 % of all electricity production in 2005 (see EN27 for more details). The majority of these external costs occur during the production of the electricity itself (i.e. from the burning of coal and release of specific pollutants to air, etc), although there is a small component associated with other parts of the fuel cycle (e.g. due to the mining and transport of the fuel). Co-generation reduces external costs[2] and gas technology cogeneration gives external costs that are only two-thirds of lower than diesel technology. The introduction of advanced technologies (such as combined cycle (CC) and pressurised fluidised bed combustion (PFBC) can also reduce substantially the external costs of fossil energy systems. Renewable energy shows the lowest damages per unit of electricity.

Nuclear external costs are in the range 0.5–0.7 Eurocent/kWh. However, these external costs factors have to be treated with caution. There are small amount of emissions of CO_2 and air pollutants associated with nuclear power but there are difficulties in assessing the risk and damage from nuclear accidents (in operation and waste disposal) associated with radioactive release (see footnote to Figure 2 for further information).

The fall in external costs observed over the period 1990 to 2005 was primarily due to a combination of (see EN09 for further information):

- fuel switching away from coal to natural gas (and a smaller component from the increased use of renewable energy, which in general leads to far lower external costs than fossil fuels);
- the ongoing improvement in generation efficiency (in part due to the use of higher efficiency gas plant), and;
- and the use of pollution abatement technology, such as Flue Gas Desulphurisation in coal plants.

In some EU countries, the decline in the external costs per unit of electricity produced was mainly the 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 and the implementation of emission abatement measures. In Eastern Europe this was triggered primarily by economic restructuring and a decline in heavy industry (in Germany this occurred in the early part of the 1990s due to reunification). By contrast, in the UK it was due primarily to economic factors whereby gas became the fuel of choice for new plant. This also led to higher overall generating efficiencies from the use of combined cycle gas turbines (CCGT).

Many of the new Member States still have some of the highest external costs on a per kWh basis. The externalities also vary between the EU-15 Member States, as a result both of the fuel mix and location. Higher damages typically occur from emissions in countries in Western Europe because of the large population affected. Countries with lower mean externalities are Austria, Finland and Sweden, reflecting their low population density (in the two latter) and greater use of nuclear and renewable energy and, in particular, hydropower. Luxembourg is also particularly low due to a high share of imported electricity, with the remainder provided largely by natural gas and renewables.

At present, energy prices and taxation often do not reflect the full extent of external costs. However, progress is being made; with the absolute level of some taxation increasing (see EN31 and EN32) and the introduction of the EU emissions trading scheme (Directive 2003/87/EC) putting a price on carbon dioxide emissions (for electricity production and large parts of industrial emissions in the EU). Full cost pricing (incorporating all environmental costs) is a long-term goal, but there are difficulties, notably the lack of consensus about the acceptability and validity of damage cost values, and the complex interaction with the existing policy landscape. In particular, the interaction with energy subsidies, which distorts the absolute and relative prices of different fuels (see EN34 for more details). It should also be highlighted that taxes or other economic instruments are not the only way to internalise external costs; regulation is a way of internalising these costs as it may have a feedback on production costs.

2. Indicator rationale

(2) It should be noted that the results presented here are for electricity generation from cogeneration only and not both heat and electricity.

2.1 Environmental context

The external costs of the energy sector are those that energy producers and consumers impose on others without paying the consequences, including the impacts of air, waste and water pollution and of climate change. The social costs are higher than the private costs as these external costs are not included in the conventional market prices for electricity, which contributes to inefficiencies in resource allocation decisions. By including external costs in market prices, such inefficiencies can be corrected.

Externalities are most commonly incorporated through environmental taxes and charges or tradable permits (such as the EU Emissions Trading Scheme). Internalising all external costs (to get full cost pricing) would be difficult in the energy sector in Europe, in particular given the range of existing energy subsidies which can act to distort energy prices, even before externalities are considered (see EN34). However, it is still desirable to assess external costs to obtain cost 'adders', which although they may be different from the true external costs, are in line with environmental objectives set through political and societal consensus.

The most extensive study concerning externalities of the energy sector is the ExternE project and a number of subsequent studies, which provides a bottom up analysis of the external costs of the fuels used in the electricity supply sector. The ExternE methodology produces a damage value, expressed per kWh electricity or per tonne of pollutant. It focuses on the cost to human health, crops, materials, forests, ecosystems and climate change. It can include damages at all fuel cycle stages from fuel extraction to generation.

Following on from the original ExternE project, the methodology for calculating external costs has been further developed and improved in a number of projects including New-Ext (2004), ExternE-Pol (2005), the cost-benefit analysis undertaken for the CAFE programme and MethodEx (2007).

2.2 Policy context

The recent EU Green Paper on Market Based Instruments for environment and related policy purposes (European Commission, 2007) emphasised the need to *improve price signals, by giving a value to the external costs and benefits of economic activities, so that economic actors take them into account and change their behaviour to reduce negative – and increase positive - environmental and other impacts.*

The Sixth Environmental Action Programme 2002-2012 (6th EAP, 2002) also stresses the need to internalise external environmental costs. It suggests a blend of instruments that include fiscal measures, such as environment-related taxes and incentives, and a phase-out of subsidies that counter the efficient and sustainable use of energy.

A particular policy is the Community Framework for Taxation of energy products and electricity (Directive 2003/96/EC replacing 92/81/EEC). Its aim is to improve the operation of the internal market by reducing distortions of competition between mineral oils and other energy products. In line with the Community's objectives and the Kyoto Protocol, it encourages more efficient use of energy so as to reduce dependence on imported energy products and limit greenhouse gas emissions. Some Member States, in particular more recent accession countries, applied for partial or total exemption on certain products, but these exemptions generally expired in 2006. It also aims to make it possible to restructure national taxation systems and achieve objectives in the environment, transport and energy fields while complying with the rules governing the single market. The European Council (EC, 2008) has recommended that the Energy Taxation Directive be reviewed to bring it more closely in line with environmental and climate change related policies. The Commission Green Paper on market-based instruments for environment and related policies (COM (2007) 140 final) outlines some of the proposed changes to the Energy Taxation Directive in more detail.

As well as this, CO_2 emissions from combustion plants larger than 20MW emissions are covered by their participation within the EU Emissions Trading Scheme (Directive 2003/87/EC). In addition to helping to internalise, at least some portion of, the external costs of climate change from power generation it will also help promote a shift to less carbon intensive fuels for electricity generation, as well as improvements in generating efficiency. A number of changes and extensions to the ETS (including a binding target of a 21% emission reduction of greenhouse gases in 2020 relative to 2005 for large sources of CO_2-emissions), have been proposed as part of proposed package on climate change and energy (COM(2008)16, 17 and 19).

Although not aimed primarily at internalising external costs, other EU policies have and will continue to help lower the overall external costs of electricity generation. The Large Combustion Plant Directive

(2001/80/EC) 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 and the use of pollution abatement technology. Smaller plants are covered under the IPPC Directive (96/61/EC) which also provides emissions limits for particular air pollutants, and emphasises the use of Best Available Techniques Not Entailing Excessive Cost. As part of a recent review of industrial emissions legislation the Commission has proposed (COM/2007/0844 final) a single new Directive, which aims to recasts seven existing Directives related to industrial emissions (including those above) into a single clear and coherent legislative instrument.

References

6th EAP (2002) Decision No 1600/2002/EC of the European Parliament and of the Council of 22 July 2002 laying down the Sixth Community Environment Action Programme, http://ec.europa.eu/environment/newprg/index.htm

CAFE, Clean Air for Europe Programme http://ec.europa.eu/environment/archives/cafe/general/keydocs.htm

EEA (2007). EMEP/CORINAIR Emission Inventory Guidebook - 2007

European Commission (2007) GREEN PAPER on market-based instruments for environment and related policy purposes COM(2007) 140 final and supporting staff working paper SEC (2007) 388 http://eur-lex.europa.eu/LexUriServ/site/en/com/2007/com2007_0140en01.pdf
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MethodEx (2007) Methods and data on environmental and health externalities: harmonising and sharing of operational estimates http://www.methodex.org/

New-Ext (2004) New Elements for the Assessment of External Costs from Energy Technologies, Report to the European Commission DG Research, Technological Development and Demonstration (Contract No: ENG1-CT2000-00129), produced by IER (Institute for Energy Economics and the Rational Use of Energy) et al.

RECaBS, 2007, Renewable Energy Costs and Benefits for Society http://www.recabs.org/

Watkiss, P.; Downing, T.; Handley, C.; Butterfield, R. (2005). The Impacts and Costs of Climate Change. Final Report to DG Environment. September 2005. Published at
http://europa.eu.int/comm/environment/climat/studies.htm

Meta data

Technical information

1. Data source (incl. data of most recent update)
   Historical emissions - European Environment Agency - European Topic Centre on Air and Climate change.
   Historical electricity data - Eurostat http://europa.eu.int/comm/eurostat/
   Marginal Damage cost factors for air pollutants (SO_2, NO_x, NMVOCs, NH_3, PM2.5) – CAFE (Clean Air for Europe) programme http://europa.eu.int/comm/environment/air/CAFE/
   Marginal damage cost factors for CO_2 and other non-environmental social costs from nuclear and non-thermal renewables: ExternE-Pol (2005).
   Estimated damage costs due to nuclear accidents are taken from RECaBS (2007)
   Marginal damage costs for CO_2 high estimate are taken from (Watkiss et al., 2005)

2. Description of data / Indicator definition
   The external costs are based upon the sum of three components associated with the production of electricity: climate change damage costs associated with emissions of CO2; damage costs (such as impacts on health, crops etc) associated with other air pollutants (NOx, SO2, NMVOCs, PM10, NH3), and other non-environmental social costs for non-fossil electricity-generating technologies. Marginal damage cost factors (cost in € per tonne of pollutant) are taken from ExternE-Pol (2005) in the case of CO2 (low estimate) and from CAFE (Clean Air for Europe programme) in the case of the other air pollutants. The damage factors for CO2 (high estimate) are taken from Watkiss et al. (2005). Marginal damage cost factors in the case of CO2 are not country specific (i.e.

all countries share the same marginal factors for CO2, one for low, 19 Euro/tonne and one for high 80 Euro/tonne). Marginal damage cost factors in the case of other pollutants are country specific. For the low estimate, the low damage factors are then applied to the level of emissions by pollutant in each Member State in 1990 and 2005 to produce a damage cost in million Euro for each pollutant for each year. Summing up the damage costs of each pollutant gives the total damage costs in each Member State for each year. The same procedure is repeated to calculate the high estimate. The other non-environmental social costs for nuclear and non-thermal renewables are taken from ExternE-Pol (2005), and for nuclear accidents from RECaBS (2007). These provide a eurocent/kWh external cost for different types of electricity technologies, which are multiplied by the quantity of electricity produced from each of these technologies, in each Member State, for 1990 and 2005 to produce a damage cost for that year in million euro. This cost is added to that associated with the emissions of CO2 and other air pollutants and the total is then divided by the overall electricity production for that year in each Member State to produce an estimate (low and high) of the external costs associated with each unit of electricity generation.

3. Geographical coverage: EU-27 excluding Cyprus, Malta, Bulgaria and Romania

4. Temporal coverage: 1990 and 2005.

5. Methodology and frequency of data collection:
   CO_2 emissions data are annual official data submission to UNFCCC and EU Greenhouse Gas Monitoring mechanism. Combination of emission estimates based on volume of activities and emission factors. Recommended methodologies for data collection are compiled in the IPCC Guidelines for National Greenhouse Gas Inventories, supplemented by the 'Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories' and the UNFCCC Guidelines.
   SO_2 and NOx 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, EEA, Copenhagen.
   Energy data collected annually by Eurostat.

6. Methodology of data manipulation:
   (see also 2. indicator definition above) The three components of the external cost shown in the indicator are:
   a) Air pollution costs for (SO_2, NO_x, NMVOCs, NH_3, PM_{10}) in each Member State calculated from: High/Low marginal damage costs (in EUR/tonne of emission) taken from CAFE multiplied by relevant emissions data from category 1A1a Public electricity and heat production. This produces a separate high and low cost for these components. CAFE only contains a value for marginal damage cost for PM2.5 rather than PM_{10}, but the set of emissions data is poor for PM2.5 compared to PM_{10}. Hence a value of Marginal damage cost for PM2.5 * 0.6 = Marginal damage cost for PM_{10} is used.
   b) CO_2 costs in each Member State calculated from: Marginal damage cost (in €/tonne emission) taken from ExternE-Pol (2005) and Watkiss et al. (2005) multiplied by relevant emissions data from 1A1a Public electricity and heat production.
   c) The non-environmental social costs for nuclear and non-thermal renewables (Hydro, Solar PV, Geothermal, Wind) in each Member State are calculated from: The marginal damage cost (in eurocent/kWh of electricity produced by the technology) multiplied by the overall level of electricity production from each technology - corresponding to Eurostat codes: 107003 gross electricity generation nuclear, 107005 gross electricity generation wind turbines; 107023 gross production from photovoltaic systems; 107001 Gross electricity generation - Hydro power plants; 107002 gross electricity generation - Geothermal power plants.
   The 3 components are summed to produce an overall damage cost for each Member State. These are then divided by Eurostat's '107000 total gross electricity generation' to produce an external cost in Eurocents/kWh.

<u>Qualitative information</u>

7. Strengths and weaknesses (at data level)
   A full set of marginal air pollutant damage cost factors are not available for Cyprus, Malta, Bulgaria and Romania and so these countries have been omitted. Also, as mentioned in section 6) above, the availability of PM2.5 emissions data under category 1A1a is poor compared to PM_{10}, so the PM_{10} emissions were applied to a modified PM2.5 marginal damage cost factor from CAFE.
   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.
   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
   For some of the emissions data the ETC-ACC gap-filling methodology has been used. 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. 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.

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

The external costs of climate change depend on the models or literature that is used. There are large uncertainties in climate change modelling. The uncertainty in the costs of climate change (external costs) concerns not only the 'true' value of impacts that are covered by the models, but also the uncertainty about the impacts that have not yet been quantified and valued. Moreover, none of the current estimates of the external costs include all the effects of climate change, which indicates that the values found in literature are only a sub-total of the full costs (the share of this sub-total in the full costs is also unknown). The external costs of CO_2 emissions are taken from ExternE-Pol (2005) and Watkiss et al. (2005). They must thus be interpreted with care, due to uncertainties based on the long-time scales involved, and the lack of consensus on future impacts of climate change itself. Watkiss et al. (2005) stress that there is no single value and that the range of uncertainty around any value depends on ethical as well as economic assumptions. The study concludes that 'a lower indicative estimate for the marginal damage costs for the full risk matrix might result in a minimum value of 15 EUR/tCO_2, a central illustrative estimate of some 25 EUR/tCO_2, and an upper indicative estimate of at least 80EUR/ tCO_2 and possibly much higher (for current, year 2000 emissions).' CO2 damage factors used in this factsheet are 19EUR/t CO_2 (based on ExternE-Pol, for the low estimate) and 80 EUR/ t CO_2 (Watkiss et al. (2005), for the high estimate).

CO_2 emission estimates:
The IPCC believes that the uncertainty in CO_2 emission estimates from fuel use in Europe is likely to be less than ± 5 %. Evaluation of uncertainty is undertaken as part of the Annual European Community greenhouse gas inventories. In 2005 for the first time uncertainty estimates were calculated for the EU-15 in EEA (2005). For energy related greenhouse gas emissions the results suggest uncertainties between +/– 1 % (stationary combustion) and +/– 11 % (fugitive emissions). The uncertainty associated with CO_2 emissions from public heat and electricity production (IPCC sector 1A1a) has been estimated at around 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.

SO_2 emission estimates:
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 (EEA 2007). 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).

NOx emission estimates:
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 2007). 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.

The external costs from nuclear have to be treated with caution, as only parts of the externalities are included. The costs reflect to a large extent the small amount of emissions of CO2 and air pollutants, radioactive emissions (primarily from downstream radioactive emissions from mine tailings along with a minor portion from operation of the plant itself). A key issue is related to the treatment of potential damage from nuclear accidents: In 2005, ExternE "Externalities of Energy", Methodology 2005 Update http://www.externe.info/brussels/methup05a.pdf concluded that radiological impacts from emissions during power plant operation and final disposal were found to be only of minor importance for the overall results from the nuclear fuel cycle. In fact, the methodology to evaluate impacts due to accidents was risk-based (risk, being defined as the probability of accident multiplied by the consequences resulting from that accident). The report states that “it is sometimes argued that, for so-called Damocles risks, i.e. risks with a very high damage and a low probability, the risk assessment of the public is not proportional to the risk. The occurrence of a very high damage should be avoided, even if the costs for the avoidance are much higher than the expectation value of the damage. However past attempts to quantify this effect have not been successful or accepted, so there is currently no accepted method on how to include risk aversion in such an analysis. Consequently it is currently not taken into account within the ExternE methodology. Research on how to assess this, for example with participatory approaches, is clearly needed”. No external costs for nuclear accidents are included in the estimates from ExternE-Pol (2005) due to the complexities in estimating this, however, By only considering its low air pollutant and CO2 emissions, and the level of non-accident related radioactivity, the external costs are considerably lower than fossil fuel generation, and broadly on a par with renewables. By contrast the RECaBs (2007) estimate used in this indicator (in addition to the other non-environmental social costs for nuclear from ExternE-Pol) is based on earlier analysis which, broadly speaking, takes historic data on nuclear accidents more directly into the assessment of the probability of a future accident occurring (e.g. Chernobyl and Three Mile Island) and its cost (primarily from data on Chernobyl). Whilst this gives a much higher probability, and by extension a higher external damage cost, the estimate is still highly uncertain for a number of reasons (as outlined in the RECaBS supporting documentation). For example: it may overestimate the probability of an accident occurring in a new state-of the art nuclear plant in Western Europe due to the fact that: serious deficiencies have been identified in the former USSR PWR design ; there was a lack of a regulatory body in the former USSR and safety culture was problematic. Alternatively it may underestimate the external cost due to: higher population densities (and hence impacts) in many Western European Countries; higher GDP – and hence greater economic consequences; increased threats of terrorism. RECaBS states that the estimate of 0.25 Eurocents/kWh also takes into account that future plants are assumed to be considerably safer than existing plants and that public anxiety about nuclear power is assigned an economic value.

There are then three further principle issues in calculating external costs from a given level of pollution. The first is in modelling the dispersion of pollutants from a source across a region or potentially Europe as a whole to examine where the damage from these pollutants is likely to occur. The second step is examining dose (or concentration) response relationships to estimate how much damage a pollutant is likely to cause at a particular point, for example, the impact on health will be higher in areas where the population is more ‘vulnerable’ (i.e. a higher proportion of children and the elderly). The third issue is how the level of damage that is caused is valued in monetary terms. In certain cases this is ‘relatively’ straightforward, for example, when air pollution affects crop yields market values for the loss of the particular crops can be used. Far more contentious is the impact on health, particularly in relation to the impact of long-term exposure to air pollution and mortality (so called chronic mortality) as there are varying methods such as VOLY (Value of Life Years which estimates the economic loss in terms of healthy Years of Life Lost or YOLL from the impact of the pollution), or the use of VSL (the Value of a Statistical Life as a whole which generally leads to much higher valuations of external costs). However, considerable uncertainties have been acknowledged regarding many aspects of the methodology that have been applied in the ExternE and follow-on projects, which have been used to help quantify and monetise the scale of these external costs. Research is continuing to reduce the uncertainties present in this type of analysis. There are considerable uncertainties in these latter steps (following the estimate of emissions/pollutants and modelling of their dispersion across the EU) of the methodology to estimate overall external costs. In particular:

- estimating the level of damage caused by a particular pollutant (the dose/concentration response relationship),
- valuing the impact of this damage in monetary terms.

This is particularly difficult in the case of health impacts whose results are due primarily to the size of the air pollution externality, which is determined by two main elements (directly based on the above 2 steps), both of which are related to the impact of long-term exposure to air pollution and mortality (so called chronic mortality):

- The quantification method used for air pollution and long-term mortality (i.e. the dose-response relationship),
- The valuation estimates used to value these changes in long-term mortality.

Chronic effects on mortality have become the main focus for quantification of the health impacts of particulate exposure. The analysis uses the risk estimates that are based on analyses of the American Cancer Society (ACS) cohort by Pope et al (1995,) and updated in 2002. The main results from the Pope et al (1995) study give a lower bound estimate of increase in death rates of 3 % per 10 µgm-3 PM2.5, a central estimate of 6 % per 10 µgm-3 PM2.5,and an upper bound estimate of 9 % per 10 µgm-3 PM2.5. ExternE-Pol (2005) uses a lower bound rate (2 or 3 % per 10 µgm-3 PM2.5). However, CAFE, following advice and guidance from WHO, uses the central estimate of 6 % per 10 µgm-3 PM2.5. Therefore the basis upon which the damage caused by the pollutants is assessed (the step before this damage is then valued) is different and CAFE will hence produce generally higher numbers than ExternE-Pol. There is also one additional difference in that CAFE assumes that all components of PM2.5 are equally hazardous. ExternE-Pol assumes that nitrates have a lower hazard to health, and uses an adjusted (and hence lower) risk rate for the nitrates.

In terms of the physical impacts quantified, the guidance from the WHO (World Health Organisation) expresses chronic mortality effects principally in terms of change in longevity. This also leads to estimates of the change in longevity aggregated across the population (otherwise referred to as 'years of life lost' or YOLL) as the most relevant metric for quantification and valuation. Both ExternE-Pol and CAFE use this metric. They also use the same estimates from NewExt (2004), in terms of the VOLY (Value of Life Years), to value these changes. However, CAFE, following advice from the peer review, also works in terms of attributable deaths from chronic mortality. The peer review of the CBA (Cost Benefit Analysis) methodology pointed out that direct, credible estimates of the VOLY are lacking, that the estimates to be used in CAFE are derived computationally and that to be applied correctly, VOLYs should be age specific. To address this, CAFE also quantified premature mortality benefits based on the cohort studies in terms of 'attributable deaths' and valued these using a Value for a Statistical Life or VSL approach (also derived from the NewExt project). This leads to a higher estimate of damage costs compared to the VOLY approach, and hence a range of values for the damage costs. NewExt provided both mean and median estimates for VOLY and VSL. ExternE-Pol used the median estimates for VOLY only. However CAFÉ based upon the above peer review advice uses both mean and median estimates for VOLY and VSL (see below). The use of both the VOLY and VSL approaches, with mean and median estimates, leads to four estimates in CAFE (VOLY median, VSL median, VOLY mean, VSL mean).

	VSL	VOLY	Derived from:
Median (NewExt)	EUR 980 000	EUR 52 000	Median value 5:1000
Mean (NewExt)	EUR 2 000 000	EUR 120 000	Mean value 5:1000

CAFE itself does not make any recommendation on which of the four estimates to use – they are all provided as four equally valid results. However, in the case of externality analysis, it is generally recommended to use the full range of low and high estimates. Hence the indicator with the high estimate is based upon CAFE's use of the Mean VSL in the assessment of the marginal damage cost factors for the air pollutants (NO_x, SO_2, NMVOCs, PM_{10}, NH_3) and the Median VOLY in the case of the low estimate.

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