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Air pollution from electricity-generating large combustion plants

An assessment of the theoretical emission reduction of SO_2 and NO_X through implementation of BAT as set in the BREFs

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Glossary

AEL	associated emission level
BAT ([1])	best available techniques
BREF	BAT reference document; http://eippcb.jrc.es/pages/FActivities.htm
CO	carbon monoxide
CO_2	carbon dioxide
EEA	European Environment Agency; http://www.eea.europa.eu/
EF	emission factor
Eionet	European Environmental Information and Observation Network of the EEA
ELV	emission limit value
EMEP	European Monitoring Evaluation Programme
EMEP/CORINAIR guidebook	Technical guidance developed to support emission reporting to the LRTAP Convention and its protocols. The EMEP/CORINAIR emission inventory guidebook (EMEP/CORINAIR) is also used in reporting under the EU NEC Directive. http://reports.eea.europa.eu/EMEPCORINAIR5
EPER	European Pollutant Emission Register; http://eper.ec.europa.eu/eper
EPER Annex A3 activity	Source categories of emissions that have to be reported under the EPER Decision, listed in Annex A3 to the EPER Decision, as referred to in the EPER decision as Annex I activities (of the IPPC Directive)
EPER Decision	Commission Decision 2000/479/EC of 17 July 2000 on the implementation of a European pollutant emission register (EPER according to Article 15 of Council Directive 96/61/EC concerning integrated pollution prevention and control (IPPC)
ETC/ACC	European Topic Centre on Air and Climate Change;
EU	European Union
EU10+2	Refers to the Member States that joined the EU in the Fifth EU enlargements (part I and part II). In 2004 and 2007, 10 (Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia) and 2 (Bulgaria and Romania) countries joined the EU respectively.
EU-25	Refers to the 25 Member States following the enlargement of the EU in 2004
GAINS	Greenhouse Gas and Air pollution INteractions and Synergies, an update of the Regional Air Pollution INformation and Simulation (RAINS) model of the International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria; http://www.iiasa.ac.at/
GJ	gigajoule = 109 Joule
IPCC 2006 guidelines	2006 IPCC guidelines for national greenhouse gas inventories;
IPPC	integrated pollution prevention and control
IPPC Annex I activities	Categories of industrial activities covered by the IPPC Directive. These can also be referred to as Annex A3 activities of the EPER Decision
IPPC Directive	Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control
Kt	kilotonne = 1 000 tonnes (metric) = 1 000 000 kg
LCP	large combustion plant
LCP BREF	Integrated pollution prevention and control reference document on best available techniques for large combustion plants, July 2006
LCP Directive	Directive 2001/80/EC of the European Parliament and of the Council of 23 October 2001 on the limitation of emission of certain pollutants into the air from LCPs
LRTAP Convention	UNECE Convention on Long-range Transboundary Air Pollution
MS	European Union Member State
MW	megawatt = 106 watt
MW_e	megawatt electrical (capacity)
MW_{th}	megawatt thermal (capacity)
NCV	net calorific value
NEC Directive	National Emission Ceilings (NEC) Directive: Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants
NMVOC	non-methane volatile organic compound
NO_x	nitrogen oxides
Platts WEPP Database	Platts UDI World Electric Power Plants Database, version September 2006; http://www.Platts.com/
PM	particulate matter
PM_{10}	particulate matter that passes through a size-selective inlet with a 50 % efficiency cut-off at 10 µm aerodynamic diameter
RAINS	Regional Air pollution INformation and Simulation model; integrated assessment model developed by the International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria; http://www.iiasa.ac.at/web-apps/tap/RainsWeb/
SO_2	sulphur dioxide
UNECE	United Nations Economic Commission for Europe

([1]) In the context of this study, BAT refers to the techniques and associated emission levels as described in the LCP best available techniques reference document (BREF).

Executive summary

The study was initiated in the context of the review of the Integrated Pollution Prevention and Control (IPPC) Directive ([2]).

This report presents the results of a study that assesses the theoretical potential to reduce air emissions of SO_2 and NO_X that might have occurred had the best available techniques (BAT) ([3]) and associated emission levels (AELs), as described in the large combustion plant best available techniques reference document ([4]) (LCP BREF), been fully introduced in a set of electricity-generating large combustion plants (LCP) within the European Union (EU-25) in 2004. A similar analysis is also provided, illustrating the potential effect of implementing the LCP Directive ([5]) emission limit values (ELVs) at the facilities included within the scope of the work. The study covers more than 70 % of the emissions of SO_2 and NO_X included in EPER for the LCP sector ([6]).

Scope of this study

This study quantifies what the emissions reduction of two important acidifying pollutants — sulphur dioxide (SO_2) and nitrogen oxides (NO_X) — would have been at an EU scale in 2004, had the large combustion plants BREF best available techniques and associated emission levels been applied in electricity-generating large combustion plants included in the study.

Several issues have not been considered to be within the scope of the study. These include consideration of ongoing changes that have occurred in the sector since 2004 (e.g., changes to plant fuel mixes; replacement of old plants with newer, more efficient and cleaner plants; operational changes with respect to plant use as peak or baseload generators; changes in emissions due to start-up/shut-down procedures; evolution in abatement equipment along with general economic growth).

The emission reductions that can be achieved in practice due to the implementation of IPPC legislation (even if not considering such factors as fuel mix changes, closures or economic growth) are therefore not necessarily the same as those indicated by this study. Hence no conclusions concerning compliance with legal requirements should be drawn. Rather the study may be viewed as a 'what-if' study that aims to quantify the potential emission reductions that are achievable by implementing the techniques presently identified in the large combustion plants BREF as best available techniques in the large combustion plants sector as it operated in 2004.

Data and methodology

Of the large combustion plants facilities included in the European Pollutant Emission Register (EPER ([7])), 450 were identified for which associated information on type of fuel used, capacity and installed abatement techniques for each facility unit could be obtained from commercially available information sources. The fuel combusted in each of these facilities was estimated based on reported CO_2 emissions under the EPER Decision ([8]).

The emissions reported in EPER for 2004 (including estimated facility emissions for 2004 where these were not reported) were subsequently compared to calculated emissions derived from the estimated fuel used and:

([2]) Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control, OJ L 257, 10.10.1996, pp 26–40.

([3]) In the context of this study, BAT refers only to the techniques and associated emission levels as described in the LCP best available techniques reference document (BREF).

([4]) Integrated pollution prevention and control reference document on best available techniques for large combustion plants (LCP BREF), European Commission, July 2006.

([5]) Directive 2001/80/EC of the European Parliament and of the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants, OJ L 309 of 27.11.2001, pp 1–21.

([6]) Facilities having main activity 1.1.

([7]) European Pollutant Emission Register; http://eper.ec.europa.eu/eper.

([8]) Commission Decision 2000/479/EC of 17 July 2000 on the implementation of a European Pollutant Emission Register (EPER), according to Article 15 of Council Directive 96/61/EC concerning integrated pollution prevention and control (IPPC), OJ L 192, 28.7.2000, pp. 36–43.

- emission factors based on the upper end of the BAT-associated emission levels from the large combustion plants BREF: 'upper end of best available techniques';
- emission factors based on the lower end of the BAT-associated emission levels from the large combustion plants BREF: 'lower end of best available techniques';
- emission factors derived from the emission limit values contained within the LCP Directive ([9]).

Although the data has been analysed at the level of individual facilities, certain assumptions have been applied in the analyses, and therefore results should be considered only at an aggregated level. The calculated estimates for individual facilities might not always be accurate, but conclusions based on aggregated data are considered valid since deviations at individual units will average out. An uncertainty and sensitivity analysis was performed to assess the overall uncertainties at EU level introduced by the main assumptions employed within the study's methodology.

Key findings: implementation of the large combustion plants BREF associated emission levels

The results of the study clearly indicate that EU-25 emissions of the air pollutants NO_X and SO_2 from large combustion plants facilities included in the scope of the study could be significantly reduced if the associated emission levels associated with the best available techniques described in the large combustion plants BREF were to be implemented. Specific findings of the report include:

- the emissions of NO_X from the large combustion plants would have been nearly 60 % lower if all plants performed according to the 'upper end of best available techniques' in 2004. If all plants would have performed according to 'the lower end of best available techniques', emissions of NO_X would have been almost 90 % lower;
- for SO_2, introducing best available techniques in all facilities would have decreased emissions from the large combustion plants by more than 80 % for the 'upper end of best available techniques' and by more than 95 % for the 'lower end of best available techniques' in 2004;
- by far the largest contributions to these estimated emission decreases would occur as a result of the full implementation of the large combustion plants BREF associated emission levels at coal-and lignite-fired large combustion plants.

Key findings: LCP Directive

The NO_X and SO_2 emissions from the 450 facilities included in this study might have been considerably lower (20 % and 61 % respectively) if all units within these facilities had met the LCP Directive emission limit values.

Since these emission limit values are less stringent than the BREF associated emission levels, the estimated potential emission reductions that could be achieved by meeting the BREF associated emission levels are even greater.

Table A Estimated emissions and the % difference compared to 2004 emissions occurring as a result of implementation of the BREF AELs in the LCPs included in this study

Pollutant	2004 EPER emissions ([10])	Estimated emissions reduction potential (kt/year) ([11])			
		'Upper end of BAT'		'Lower end of BAT'	
		kt	%	kt	%
NO_X	1 506	884	– 59 %	1308	– 87 %
SO_2	2 853	2287	– 80 %	2754	– 97 %

Source: Based on EPER, 2006 and Platts, 2006.

([9]) The LCP Directive analysis applies the ELVs to be applied by new and existing plants pursuant to Article 4(1) and 4(3) respectively (for the latter, the ELVs apply from 1 January 2008). In this work, the process used to estimate emissions does not take into account any exemptions, derogations or specifications in national reduction plans.

([10]) Including estimated facility emissions for 2004, where these were not reported in EPER.

([11]) For those plants that have reported emissions below the estimated emissions corresponding to the BREF AELS, no emission reduction potential is assumed.

1 Introduction

1.1 Background

Emissions from LCPs

Historically, large combustion plants (LCPs) have been a significant source of emissions of the acidifying air pollutants sulphur dioxide (SO_2) and nitrogen oxides (NO_X), and other air pollutants that potentially impact upon human health and the environment, including particulate matter (PM), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOC).

The introduction of various air pollution legislation measures and their subsequent implementation by industry has seen the level of emissions from LCPs fall. E.g., reported EU-25 emissions of NO_X and SO_2 from the electricity and heat production sector for 2004 were 44 % and 70 % lower respectively, compared to 1990 levels. Over the same period, total EU-25 NO_X and SO_2 emissions fell by 32 % and 71 % respectively (EEA, 2008). Future emissions from this sector are predicted to decrease even further. Modelling work performed on behalf of the European Commission indicates, e.g., that EU-25 emissions of NO_X and SO_2 from the electricity and heat production sector are projected to fall by 15 % and 40 % respectively by 2010 (compared to 2005 emission levels), and for both pollutants by around a further 25 % by 2020 (IIASA, 2007a).

However, despite the decreases in emissions that have occurred, this sector remains an important source of key air pollutants, as illustrated by emissions of SO_2 and NO_X included in EPER (EC, 2006) from combustion facilities ([12]), which amount to 54 % and 18 % respectively of the reported total EU-25 emissions (all sources) (EEA, 2008) and to 74 % and 61 % respectively of the total emissions included in EPER for the year 2004.

EU legislation

Within the European Union, emissions from large combustion plants are regulated under the Integrated Pollution Prevention and Control (IPPC) Directive 96/61/EC (EC, 1996) and the Large Combustion Plants (LCP Directive 2001/80/EC (EC, 2001a).

The IPPC Directive covers a number of industrial sectors (including combustion plants with a rated thermal input exceeding 50 MW) and aims to reduce their overall environmental impact through a process of integrated permitting. Member States (MS) must ensure that Emission Limit Values (ELVs) in line with best available techniques (BAT) are included in an integrated permit issued by the competent authority for each IPPC installation. The Directive includes a definition of BAT, supplemented by an annexed list of considerations that allow for the determination of BAT on a case-by-case basis.

The IPPC Directive came into force on 30 October 1996 with a transposition deadline for new and substantially changed installations by 30 October 1999 and for existing installations by 30 October 2007. Since the latter date, all IPPC installations have been required to operate in accordance with the requirements of the Directive. As per Article 16 of the Directive, an exchange of information on best available techniques has been undertaken, culminating in the creation of BAT Reference documents (BREFs). The BREFs are not legally binding but provide information on the best environmental performance associated with technically and economically viable techniques.

The Commission adopted the LCP BREF (EC, 2006) and published it in July 2006. It contains BAT associated emission levels (AELs), which for air pollutants are generally expressed as flue gas pollutant concentrations.

Taking into account the October 2007 deadline for the IPPC Directive implementation for existing installations and the publication of the LCP BREF in mid 2006, it is probable that some competent authorities were not able to use this BREF when establishing the integrated permits for the LCPs.

The LCP Directive entered into force on 27 November 2001 with a transposition deadline one year later. The Directive sets ELVs for SO_2, NO_X and dust into the air from combustion plants with

([12]) Facilities with main activity 1.1 or with installations having a rated thermal input above 50 MW.

a rated thermal input equal to or exceeding 50 MW. New combustion plants (licensed after 1 July 1987) must meet the ELVs given in the LCP Directive. A distinction is made between new plants licensed before and after 27 November 2002, with the latter ones having to meet more stringent ELVs. For existing plants (licensed before 1 July 1987), Member States can choose to meet the obligations of the Directive by 1 January 2008 by either:

- requiring plant-by-plant compliance with the ELVs for NO_X, SO_2 and dust that apply for new plants (pre-2002); or
- implementing a national emission reduction plan (NERP), which sets an annual maximum level of emissions for all of the plants covered by it.

Meeting the ELVs of the LCP Directive should be regarded as a necessary but not necessarily sufficient condition for compliance with the IPPC Directive.

The European Pollutant Emission Register (EPER) Decision (EC, 2000a) assures an inventory of the principal emissions of IPPC installations (including combustion installations with a rated thermal input exceeding 50 MW). For which, all emissions above specific thresholds (as defined in Annex A1 of the EPER Decision) should be reported.

On 21 December 2007, the European Commission adopted a proposal for a Directive on industrial emissions (integrated pollution prevention and control) (EC, 2007b). This proposal combines elements from seven existing pieces of legislation (including the IPPC Directive and the LCP Directive) into a single Directive. Amongst the changes proposed are a stricter definition of BAT, which leaves less flexibility for competent authorities to set permit conditions outside the BAT ranges, and the introduction of tighter minimum ELVs for LCPs to be applied after 2016.

1.2 Objectives of this report

Against the background of the review of the IPPC and LCP Directives, and taking into account the significant contribution to emissions made by LCPs, the EEA commissioned its European Topic Centre on Air and Climate Change (ETC/ACC) to undertake a study to:

a) quantify/estimate the theoretical emissions that would have occurred had LCPs fully implemented the best available techniques and associated BREF AELs in 2004 and;

b) compare these estimated emissions with the emissions data reported under the EPER Decision for the year 2004 to establish the potential reduction in emissions for this year.

1.3 Scope of the report

This report does not include a time axis or time trends in either activity data (economic growth) or technological developments.

The study quantifies what the emissions reduction of two important acidifying pollutants (SO_2 and NO_X) might have been at an EU scale in 2004 had the BREF AELs been achieved at all LCPs included in the study (electricity-generating LCPs). The study is therefore a theoretical assessment for a given point in time, namely the year 2004.

Given the aims of the work it is important to note that several issues have not been considered to be within the scope of the study. These include consideration of ongoing changes that have occurred in the sector since 2004, e.g. changes to plant fuel mixes, replacement of old plants with newer, more efficient and cleaner plants, operational changes with respect to plant use as peak or baseload generators, changes in emissions due to start-up/shut-down procedures, evolution in abatement equipment and economic growth.

The emission reductions that can be achieved in practice by the implementation of the IPPC legislation (even if not allowing for fuel mix changes, closures, economic growth, etc.) are therefore not necessarily the same as those indicated in this study. Hence no conclusions concerning compliance with legal requirements should be drawn. Rather the study may be viewed as a 'what-if' study that aims to quantify the potential emission reductions that could be achieved by implementing the techniques presently identified in the LCP BREF as BAT.

The study does not deal with the legal interpretation nor the transposition and implementation of the IPPC or LCP Directive in national law or in actual permits issued under national regulations.

1.4 Terminology

Terminology used within EU legislation relating to industrial emissions is not always consistent and/or comparable. This section explains the specific terminology used in the context of this report (see also the Glossary).

a) Associated emission level (AEL)

An associated emission level (AEL) is a level of emission that should be achieved when BAT as described in a BREF is applied for a specific installation. For air pollutants AELs are generally expressed as concentrations in flue gases. 'BREF AELs' refer to the associated emission levels presented in the LCP BREF.

b) Best available techniques (BAT)

The IPPC Directive provides a definition of BAT that is supplemented with a list of 12 considerations that allow for a determination of BAT generally or in specific cases. In the context of this work, it is not possible to use a case-by-case definition of BAT and therefore the best available techniques as described in the LCP BREF are used to define BAT for LCPs.

c) 'Lower end of BAT' and 'upper end of BAT'

Within the LCP BREF, ranges of BAT AELs are given for a number of air pollutants. Within this report, these AEL ranges are translated into 'lower end of BAT' based on the lower end of the ranges of the BAT AELs and 'upper end of BAT' based on the upper end of the ranges of the BAT AELs.

d) Large combustion plant (LCP)

This study focuses on EPER facilities:

1. with a main activity 1.1 within Annex 1 of the IPPC Directive (facilities for which the units have an aggregated rated thermal input exceeding 50 MW);

2. for which reported emissions of CO_2 are included in EPER for 2004; and

3. that could be linked to the Platts World Electrical Power Plant (WEPP) Database (Platts, 2006) (a commercial database containing details of industrial combustion facilities). Further details about the database are given later in the report.

Due to the linking with the Platts WEPP Database, the EPER facilities selected are all electricity-generating, and should not have emissions occurring from activities other than activity 1.1 on their site.

e) IPPC Annex I Activity 1.1 or EPER Annex A3 Activity 1.1

In the context of this document, activity 1.1 refers to the activity 1.1 as included in Annex I of the IPPC Directive. These can also be referred to as Annex A3 activities of the EPER Decision. Activity 1.1 covers combustion installations with a rated thermal input exceeding 50 MW.

f) Main activity

If an EPER facility covers more than one Annex I activity to the IPPC Directive, a 'main activity' is defined by the operator for that facility. This facilitates the inclusion of the facility in the EPER database. The rules for the identification of the main activity are provided in the EPER Guidance Document ([13]).

g) Installation, facility and unit

In this report, the terms installation and facility are used as defined in the IPPC Directive and the EPER Decision respectively. The term unit is used as defined in the Platts WEPP Database.

- Installation: IPPC Directive — Article 2.3

  In the context of the report, the IPPC Directive (Article 2.3) definition of installation is used: 'Installation shall mean a stationary technical unit where one or more activities listed in Annex I are carried out, and any other directly associated activities which have a technical connection with the activities carried out on that site and which could have an effect on emissions and pollution'.

  The same definition of installation is provided in the EPER Decision (Annex A4).

- Facility: EPER Decision — Annex A4

  In this report, the EPER Decision (Annex A4) definition of facility is used: 'Industrial complex with one or more installations on the same site, where one operator carries out one or more Annex I activities to the IPPC Directive'.

- Unit: Platts WEPP Database (Platts, 2006)

In this report, the Platts WEPP Database definition of unit is used. The Platts WEPP Database includes information on a generating unit basis whenever

([13]) http://www.eper.ec.europa.eu/eper/guidance.asp.

possible. A 'unit' may be termed a set, block, or section in other sources. For typical steam-electric plants, a unit comprises a steam generator (boiler or reactor), a steam turbine (the prime mover) and a generator. When a series of boilers are connected to a common steam header, the unit designations are applied to the prime movers and the boiler-related data are assigned to the unit records as appropriate.

Note: 'installation', as defined in IPPC and 'unit' as used in the Platts WEPP Database are not synonymous. The latter might be closer to the physical reality at a specific facility or location. The 'technical connection' concept, used in the definition of an installation in IPPC, means that an IPPC installation can consist of one or more units as defined in the Platts WEPP Database.

2 Data and methods

2.1 Introduction

To allow calculation of the theoretical emissions from electricity-generating LCPs, it would be optimal to have access to the following information for each of the units in every LCP:

- thermal capacity;
- type of fuel used (fuel-use split);
- amount of fuel used;
- technology used (electricity-generating technology and abatement technology);
- emission factors (EFs) for the different pollutants;
- flue gas volumes;
- total annual emissions.

This information is however not available through any present EU reporting obligation or commercially-available database.

This study therefore required development of a specific methodology. The methods developed for the assessment combine information from the EPER data set 2004, the Platts WEPP Database 2006 and emission-related data from different sources (e.g., the EMEP/CORINAIR guidebook (EMEP/CORINAIR, 2007) and IPCC guidelines (IPCC, 2006). The developed method also necessitates the use of a number of assumptions and approximations. The respective data sets and methods used are discussed in more detail in the following sections.

2.2 Development of the primary data set used in this study

2.2.1 EPER 2004 data set

The assessment in this report is based on the emissions to air for 2004 that were reported by EU Member States (MS) under the EPER Decision in 2006 and that are included in the EPER database ([14]). The EPER 2004 data set used in this analysis is the same as the data set used in the EPER 2004 Review report (EC, 2007a). It reflects the MS corrections made in January 2007 during the second official correction round of the data set.

The EPER database stores data at the level of individual facilities. Each facility will have one or more so-called EPER Annex A3 activity ([15]). In cases where more than one EPER Annex A3 activity is mentioned, one of these is labelled as 'main activity'. According to the EPER Guidance document (EC, 2000b) the main activity is the activity that contributes the most to the releases of pollutants to the environment (see also Section 1.4).

The EPER 2004 data set contains emission data on 11 505 facilities. For 1 708 of these, EPER Annex A3 activity 1.1: 'Combustion installations > 50 MW' is reported; in 1 268 facilities, this activity was marked as 'main activity'. To avoid bias in the analyses due to emissions from industrial processes, only these 1 268 facilities, reporting activity 1.1 as their main activity are included in this study. This implies that the selection mainly covers the power-generating sector and to a lesser extent the industrial combustion plants.

The EPER data set does not include information at the facility or unit level concerning capacity (in terms of production volumes or fuel use), types of fuels used, technology, flue gas volumes, etc., and hence the EPER data themselves are not sufficient to make an assessment of potential emission reduction potentials. To overcome this lack of information, the EPER data were linked to a commercially available data set (the Platts WEPP Database), which contains information on specific operational parameters at a power plant unit level.

2.2.2 Platts WEPP Database

The Platts WEPP Database (Platts) contains information about power plants on a generating unit

([14]) http://eper.ec.europa.eu/eper.

([15]) The EPER decision links IPPC Annex I activities to reporting obligations in Annex A3 of the EPER Decision. Since in this report EPER data are used, we use the terminology 'EPER Annex A3 activity'.

basis whenever possible. It provides information on, e.g., the type of fuel used, abatement installed and electrical capacity. As was noted in Section 1.4 (Terminology) a 'unit' according to the Platts WEPP Database may be termed a set, block, or section in other sources. For typical steam-electric plants, a unit is comprised of a steam generator (boiler or reactor), a steam turbine (the prime mover), and a generator. In cases where a series of boilers are connected to a common steam header, the unit designations are applied to the prime movers and the boiler-related data are assigned to the unit records as appropriate.

The Platts data used in the study comprised a number of parameters concerning plant location and unit characteristics: fuel type, capacity (MW_e), the present status of the unit (operational, planned, closed down, etc) and information on installed abatement technologies.

2.2.3 *Linking of the EPER data set and the Platts WEPP Database*

The Platts WEPP Database contains information at a unit level for combustion plants (e.g., boilers and turbines), whereas the EPER data set contains emissions aggregated at the facility scale. EPER facilities can therefore include multiple combustion units of different types and fuel use, amongst others.

Since EPER does not include information on the type of fuel used in these combustion facilities, and the Platts WEPP Database provides fuel information at the level of 'units' within electrical power plant 'companies', the Platts 'companies' were linked to the EPER facilities as far as possible on the basis of company names and locations. In this way, only the EPER facilities with a main activity 1.1 and producing electrical power, were retained from the EPER data set.

Using this linking process, the units within each Platts WEPP Database location belonging to an EPER facility were identified allowing fuel and capacity information from the Platts WEPP Database to be linked to a total of 528 EPER facilities.

2.2.4 *Final data set selection for the study*

The capacity and fuel information from the Platts WEPP Database (unit level) was subsequently used together with the CO_2 emissions reported in EPER in order to estimate the fuel quantity used at each unit in 2004. The EPER database only contained CO_2 emission data for 450 of the 528 EPER facilities linked to the Platts Database. These 450 facilities were linked to 1 482 individual units in the Platts WEPP Database. As noted in section 1.4, the facilities selected should be solely electricity-generating facilities.

Although only 35 % of the EPER facilities with a main activity 1.1 could be matched to the Platts WEPP Database, Table 2.1 and Figure 2.1 show that the percentage of the total EPER emissions accounted for from this sector was 70 % or greater for the pollutants CO_2, NO_X, SO_2, NMVOC, PM_{10} and CO. This was considered an acceptable coverage for the purposes of this study.

Annex A provides more detailed information on the process of data linking between the EPER and the Platts WEPP Database.

2.3 Methodology

2.3.1 *Overview*

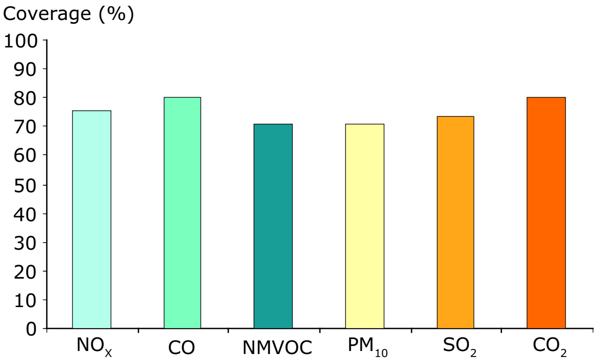
The overall approach developed for estimating the emissions reduction potential that could occur

Table 2.1 Emissions of the 450 selected EPER facilities compared to the emissions of all 1 268 combustion facilities (having main activity 1.1) in the EPER 2004 data set (kt)

Pollutant	Emissions from the 450 selected EPER facilities (kt)	Total reported emission of all EPER facilities with main activity 1.1 (kt)	% of total EPER emissions from main activity 1.1 covered by facilities included in this study
NO_X	1 494	1 986	75
CO	207	257	80
NMVOC	6	9	71
PM_{10}	91	128	71
SO_2	2 773	3 771	74
CO_2	1 006 598	1 259 325	80

Source: Based on EPER, 2006 and Platts, 2006.

Figure 2.1 Coverage of emissions from the selected 450 EPER facilities compared to emissions of all 1 268 EPER combustion facilities (having main activity 1.1)



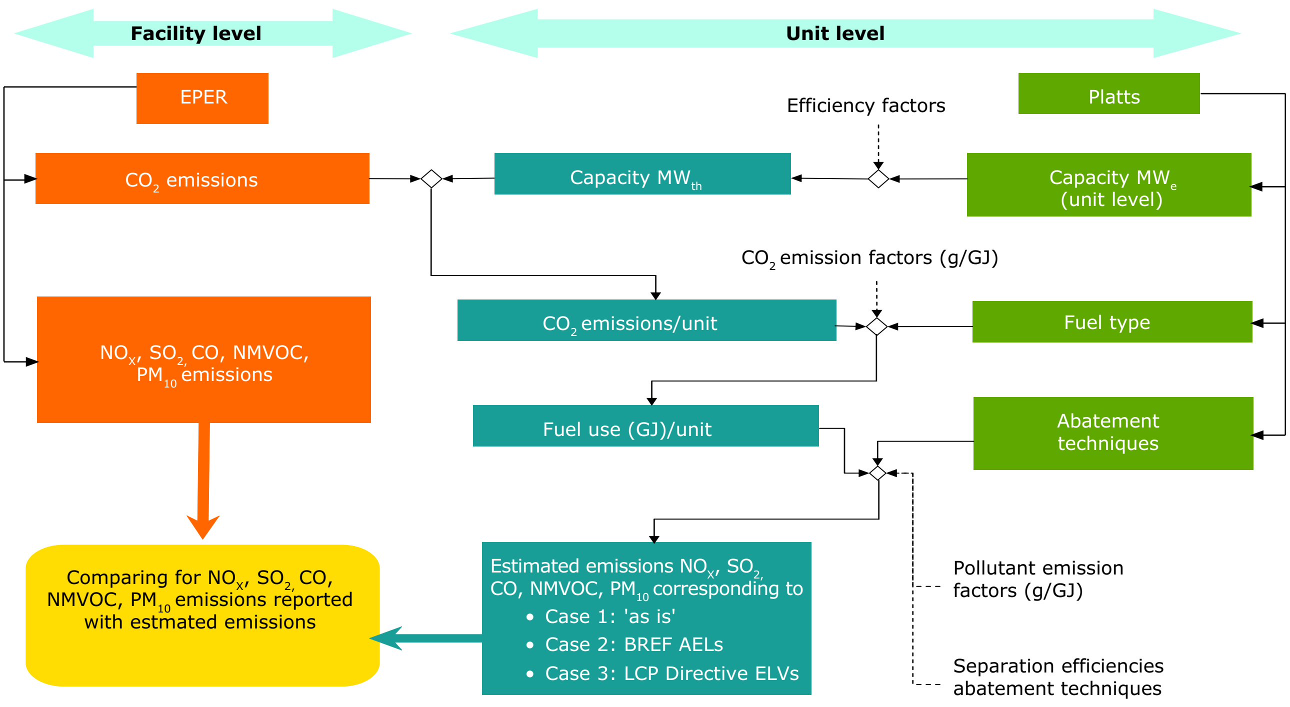
Source: Based on EPER, 2006 and Platts, 2006.

following the full implementation of BREF AELs comprises five main steps:

- Step 1: Estimate of the total thermal capacity per unit;
- Step 2: Estimate of CO_2 emissions and fuel use (GJ) per unit;
- Step 3: Estimate of emissions of NO_X, SO_2, CO, NMVOC, and PM_{10} for three different cases:
  - Case 1: the 'as is' case — based on the reported EPER emissions supplemented by estimated emissions for those instances where no emissions were reported to EPER (e.g., where facility emissions may have been below the EPER reporting threshold)
  - Case 2: all units have emissions not higher than the level corresponding to the BREF AELs
  - Case 3: all units have emissions not higher than the level corresponding to the LCP Directive ELVs;
- Step 4: Estimate of completeness of EPER reporting;
- Step 5: Comparison of the aggregated facility emissions for each of the three cases with the reported emissions in EPER.

Each step is described in the following sections of this chapter. Figure 2.2 illustrates the overall methodological process used for estimating the emissions and the comparison of the estimated emissions with the emissions reported under the EPER Decision.

Figure 2.2 Schematic representation of the estimation approach



Source: Based on EPER, 2006 and Platts, 2006.

2.3.2 Step 1: estimating the total thermal capacity per unit

The capacity information in the Platts WEPP Database is given in gross electrical megawatts (MW_e) ([16]). The thermal capacities on unit level can be derived from this MW_e rating using assumed energy efficiencies for the units ([17]) as listed in Table 2.2 below. The resulting distribution of the units over the three capacity classes is listed in Table 2.3.

It should be noted that efficiency factors are strongly related to the applied technology at the specific plant. E.g., if a plant is a combined-heat-and power (CHP) plant, the electrical efficiency is substantially lower than that of a traditional plant. Similarly, a peak load plant has a lower efficiency than does a base load plant. This affects the calculated thermal capacity figure (MW_{th}) and consequently the outcome of the estimate. In addition, across the EU there are large differences in fuel quality (natural gas, coal, oil) and the efficiency of applied abatement techniques. The assumed efficiency factors in Table 2.2 do not take these issues into account. To investigate the effect of this assumption, Chapter 4 provides details of an analysis assessing the contribution to uncertainty arising from the use of these assumed efficiency factors.

Table 2.2 Assumed efficiency factors for different fuel types

Fuel type	Efficiency factor*
Hard coal, brown coal, fuel oil, other oil	40 %–36 %
Gas	40 %–38 %

Note: *The lower efficiency factor is used in the analysis in order to take a conservative approach and prevent an underestimate of thermal capacity as far as possible

Source: BREF LCP (EC, 2006) for existing plants, Tables 2, 3 and 4.

Table 2.3 Distribution of unit capacities

(MW_{th})	Number of units estimated
50–100	339
100–300	361
>300	782
Total	**1 482**

Source: Based on EPER, 2006 and Platts, 2006.

2.3.3 Step 2: estimating CO_2 emissions and fuel use (GJ) per unit

On the basis of the estimated thermal capacities of the individual units (step 1), the reported CO_2 emissions at facility level (EPER 2004 data set) were subsequently allocated to the different units as follows:

$$[CO_2]_{unit} = [CO_2]_{facility} \times \frac{Cap_{unit} \times EF_{CO_2 fuel_{unit}}}{\sum_{all\ units} Cap_{unit} \times EF_{CO_2 fuel_{unit}}}$$

where:

$[CO_2]_{unit}$ = allocated CO_2 on unit level (kg)

$[CO_2]_{facility}$ = EPER 2004 reported CO_2 on facility level (kg)

Cap_{unit} = estimated thermal capacity rating of unit (MW_{th})

$EF_{CO_2, fuel}$ = fuel-dependent CO_2 emission factor per unit (g/GJ) as listed in Table 2.4

Using the allocated levels of CO_2 emissions for each unit, the quantity of fuel used (in GJ) by each unit was estimated using the IPPC Guidelines (IPPC, 2006) CO_2 emission factors (Table 2.4) using the following formula:

$$Fuel_{unit} = [CO_2]_{unit} / EF_{CO_2, fuel}$$

This approach implicitly assumes that all individual units within a facility have equal operation times on an annual basis. Different assumptions would have been possible for the operation times. An alternative assumption could, e.g., be derived from the observation that solid fuels are typically used in base load facilities, whereas natural gas is typically used in peak load units. Following this assumption, coal units will operate for about twice the number of hours compared to the middle load units (oil) and about four times the operating hours of peak load units on gas (see also the table concerning operating hours in Annex E). The sensitivity of the results in terms of this assumption has been tested. This issue is discussed in Chapter 4.

The consistency of the estimated fuel used per unit (in GJ) with the estimated thermal capacity was checked at unit level. This was done by calculating

([16]) The Platts WEPP Database capacity value is preferentially gross megawatts electric (MW_e). In many cases no defined value is available, so the database includes whatever value is included in the primary source documentation. Capacity ratings are often not standardised, frequently differ from source to source and can change.

([17]) For units in Platts WEPP Database indicated as using different fuel types, the assumed energy efficiency applied for the unit is the one for the main fuel used at unit level.

Table 2.4 Fuel-dependent CO_2 emission factors (g/GJ)

Fuel	CO_2 emission factor (95 % confidence interval)
Hard coal	94 600 (89 500–99 700)
Brown coal	101 000 (90 900–115 000)
Fuel oil	77 400 (75 500–78 800)
Other oils	74 100 (72 600–74 800)
Gas	56 100 (54 300–58 300)

Source: IPCC 2006 guidelines (IPCC, 2006).

the operational hours that would be required to burn the estimated fuel used at unit level under the condition of the thermal capacity of that unit. In 120 out of the 1 482 units (8 %), the estimated operation time exceeded 8 760 hours (i.e. the total number of hours per year). In these instances, where the methodological approach led to a conflict between estimated thermal capacity and attributed CO_2 emissions, the respective thermal capacities were re-estimated using the averaged operation time of all the units having the same fuel and for which estimated operation times were lower than 8 760 hours.

$$\frac{\text{Fuel use}_{unit}}{\langle\text{operation time}\rangle_{fuel}} = \text{Thermal capacity } (MW_{th})$$

where:

$\langle\text{operation time}\rangle_{fuel}$ = average operation time (in seconds) of all the units that have an estimated operation time lower than 8 760 hours when calculating the thermal capacity (MW_{th}) on the basis of the electrical capacity (MW_e).

The averaged operation times for the other 1 362 units that do not show a conflicting result are given in Table 2.5.

2.3.4 *Step 3: estimating NO_X and SO_2 emissions for three different cases*

Case 1: determining/estimating 2004 'as is' emissions:

- If emissions are reported under EPER, the 'as is' emission is taken to be the EPER emission value;
- If no EPER data are reported on facility level, the emission of a specific pollutant was estimated at unit level using knowledge of the fuel type and abatement technology from the Platts WEPP Database (in order to select an appropriate emission factor) and the estimated fuel use. Unit-level emissions were subsequently aggregated to the facility level to determine the estimated 'as is' emission.

This procedure leads to a gap-filled data set. 'As is' emissions were also estimated for the pollutants CO, NMVOC and PM_{10}.

Case 2: estimated emissions not higher than the level corresponding to the LCP BREF associated emission levels (AELs):

- Emissions at a unit were estimated using emission factors corresponding to BREF AELs prior to aggregation of the unit emissions to the facility level;
- If the estimated value was higher than the 'as is' emission, the 'as is' emission was retained and deemed to be the emission level corresponding to as a minimum the BREF AELs.

Case 3: estimated emissions not higher than the level corresponding to the LCP Directive ELVs:

- Emissions at a unit were estimated using emission factors corresponding to LCP Directive ELVs prior to aggregation of the unit emissions to the facility level;
- If the estimated value was higher than the 'as is' emissions, the 'as is' emission was retained and deemed to be the emission level corresponding to as a minimum the LCP Directive ELVs.

Some specific background issues concerning gas-fired plant are provided in Section 4.2.3.

Table 2.5 Average estimated operation times (on the basis of the estimated fuel use) for each fuel type and averaged over the units in the study

	Hard coal	Brown coal	Fuel oil	Other oil	Gas
Average	4 276	4 354	6 179	2 796	3 746
Standard deviation	2 035	1 725	1 616	1 793	1 571
Number of units	397	174	229	103	459

Source: Based on EPER, 2006 and Platts, 2006.

Case 1: determining/estimating 2004 'as is' emissions

If no emissions data were available in EPER for a certain facility/pollutant combination (e.g., where facility emissions may have been below the EPER reporting threshold), the emissions were estimated at a unit level for that facility and aggregated to the facility.

In these cases, for each unit, an emission estimate was made based on the information available in the Platts WEPP Database concerning the fuel type (which was translated in the context of the study to an assumed main fuel type, see Table 6.2), the technology installed at unit level and the estimated fuel used (see Section 2.3.3). Emissions at unit level were estimated in two phases: first unabated emissions were estimated, followed by application of abatement efficiencies applicable for the individual units.

To estimate the unabated emissions, fuel-specific emission factors (see Table 6.3) derived from GAINS (IIASA, 2007b) and the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2007) were applied for each of the pollutants assessed.

$$\text{Unabated emission}_{\text{pollutant, unit}} = \text{Fuel use}_{\text{unit}} \times \text{EF}_{\text{pollutant,fuel}}$$

where:

$\text{Unabated emission}_{\text{pollutant, unit}}$ = unabated emissions for a specific pollutant in the unit concerned

$\text{Fuel use}_{\text{unit}}$ = fuel use in the unit concerned

$\text{EF}_{\text{pollutant, fuel}}$ = fuel-specific emission factor for a given pollutant

Unabated emissions were subsequently multiplied by the relevant abatement efficiencies of the techniques implemented (identified according to the Platts WEPP Database) for each unit.

According to the Platts WEPP Database the number of units where abatement is installed were 1 405 for NO_X, 864 for SO_2 and 868 for PM_{10}. This is 95 %, 58 % and 59 % of the 1 482 units used in this study respectively.

Annex B provides detailed information concerning the abatement techniques included in the Platts WEPP Database, the unabated emission factors and the separation efficiencies used for the estimates described above (Table 6.3, Table 6.4, Table 6.5 and Table 6.6).

Case 2: estimating facility emissions not higher than the level corresponding to the BREF AELs

a) Emission estimates at unit level corresponding to BREF AELs

The LCP BREF does not define ELVs but instead refers to BAT AELs, which are typically expressed as ranges of pollutant concentrations in flue gases.

The emission factors consistent with these AELs for each fuel were calculated as follows:

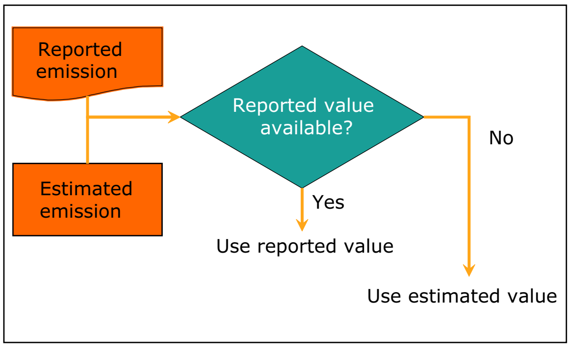
$$\text{EF}_{\text{fuel, pollutant}} = \text{AEL}_{\text{fuel, pollutant}} \times \text{(specific flue gas volume [in mass/energy unit]}$$

Annex B provides the BREF AEL ranges (Table 6.7), the flue gas volumes used in this study (Table 6.8) and the calculated LCP BREF consistent emission factors (g/GJ) (Table 6.9).

b) Comparison of estimated unit emissions with 'as is' emissions

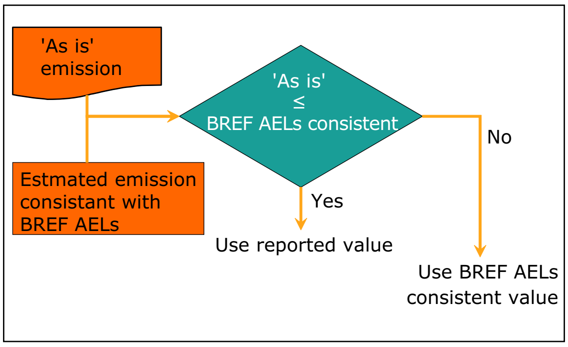
In some instances, the 'as is' emissions could in fact be lower than the estimated emissions corresponding

Figure 2.3 Case 1: Gap-filling procedure to estimate the present 'as is' (2004) emissions



Note: For all facilities and all pollutants.

Figure 2.4 Case 2: Estimating emissions not higher than the level corresponding to the BREF AELs



Note: For all facilities and all pollutants.

to BREF AELs aggregated at facility level. This may be the case e.g., where a facility is already operating beyond the BREF AELs. In such cases, it was considered that there is no further emission reduction potential and hence the 'as is' emission was taken to be the emission level corresponding to the BREF AELs.

Case 3: estimating emissions not higher than the level corresponding to the LCP Directive ELVs

a) Emission estimates at unit level corresponding to LCP Directive ELVs

The LCP Directive defines ELVs for NO_X (Annex VI of the LCP Directive), SO_2 (Annex III, IV and V) and dust (Annex VII). LCP Directive ELV consistent emission factors were calculated from these flue gas concentrations as described above for the BREF AELs.

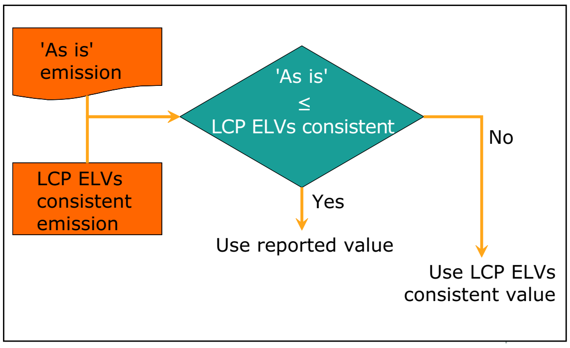
The LCP Directive analysis uses the ELVs to be applied by new and existing plants pursuant to Article 4(1) and 4(3) respectively (for the latter, the ELVs apply from 1 January 2008 onwards). The methodology does not take into account any exemptions, derogations or specifications in national reduction plans.

Annex B provides detailed information concerning the LCP Directive ELVs applied in the study for NO_X and SO_2 (Table 6.10) and the emission factors derived from them (Table 6.11).

b) Comparison of estimated unit emissions with 'as is' emissions

Where 'as is' emissions were lower than the estimated emissions corresponding to LCP Directive ELVs aggregated at facility level, it was considered that there is no further emission reduction potential and hence the 'as is' emission was taken to be the emission level corresponding to the LCP Directive ELVs.

Figure 2.5 Estimating emissions not higher than the level corresponding to the LCP Directive ELVs



Note: For all facilities and all pollutants.

2.3.5 *Step 4: estimating completeness of EPER reporting*

The comparison of the 'as is' emissions with the emissions as reported in EPER provides an estimate of the completeness of the EPER reporting. The EPER reporting can be incomplete for two reasons:

- Emissions of some pollutants at certain facilities might be below the reporting threshold;
- Facilities might not have reported emissions above the reporting threshold.

2.3.6 *Step 5: estimating the theoretical emission reduction potential of NO_X and SO_2 at facility level*

Estimating the theoretical emission reduction potentials of NO_X and SO_2 emissions uses the three different emission estimates:

1. The gap-filled 'as is' emission estimates for all facilities in this study as they were in 2004, including those that are below threshold or did not report for other reasons ('Case 1');
2. The case where all facility units have emissions not higher than the level corresponding to the BREF AELs ('Case 2');
3. The case where all facility units have emissions not higher than the level corresponding to the LCP Directive ELVs ('Case 3').

The theoretical emission reduction potentials of NO_X and SO_2 were estimated by comparing the EU-25 aggregated results for the 'as is' case (Case 1) with the two other cases (Cases 2 and 3, respectively).

The emission reduction potentials for the pollutants PM_{10}, CO and NMVOC were not estimated since reporting in EPER for these pollutants was inconsistent with the national inventories and appeared to be rather incomplete (Section 3.2). For the analyses presented in the following chapter (Results and discussion), it is sometimes necessary to specify the fuel to which each EPER-reported emission relates. In cases where the EPER-reported emissions are given in relation to associated fuel types, these emissions were distributed over the different fuels used within the units of each facility using the ratio of the estimated emissions at each unit.

3 Results and discussion

3.1 Introduction

This chapter describes the results of the analyses to estimate the theoretical emission reduction potential of NO_X and SO_2 emissions at facility level. The results comprise:

1. estimates of the completeness of EPER reporting;

2. estimates of the theoretical emission reduction potential of SO_2 and NO_X due to the implementation of BREF AELs; and

3. estimates of the theoretical emission reduction potential of SO_2 and NO_X due to the implementation of LCP Directive ELVs.

In addition, the results of a verification exercise deriving implied emission factors from EPER data are discussed in the final section of this chapter. This work was performed to verify the applicability of the approaches used in the study.

3.2 Estimating the completeness of EPER 2004 reporting

Estimated 'as is' emissions for NO_X, SO_2, CO, NMVOC and PM_{10} at facility level were compared with the pollutant-specific EPER thresholds (EPER Decision, Annex A1) and emissions above the EPER pollutant reporting thresholds were identified.

An overview is provided in Table 3.1 of (i) the emissions reported to EPER in 2004 and (ii) the total estimated emissions after gap filling was performed for the full set of 450 facilities included in this study. The table also provides an estimate of the facility emissions that were estimated to exceed the reporting threshold but which were not reported (the last two columns of the table). It can be concluded that for this set of facilities:

- Reporting of NO_X and SO_2 appears to be fairly complete, since reported emissions amount to 99 % and 97 % respectively of the estimated emissions that lie above the EPER reporting threshold;

- The estimated emissions above the EPER reporting threshold reveal that for a considerable number of facilities, emission reports of CO, NMVOC and PM_{10} might be missing in EPER, since reported emissions amount to only 47 %, 27 % and 5 % respectively of the gap-filled emission estimates.

The results shown in Table 3.1 should be interpreted with caution as the estimates may

Table 3.1 Estimated missing air pollutant reports in the 2004 EPER data set (for the selected set of 450 facilities)

Pollutant	EPER threshold (t/year)	Estimated emission (kt/year)			Difference of estimated emissions above pollutant threshold and reported emissions	
		Total reported emission in EPER	Gap-filled emissions for all selected facilities	Total estimated emission above pollutant threshold	kt	Indication of completeness* %
NO_X	100	1 494	1 506	1 506	12	99 %
SO_2	150	2 773	2 853	2 851	79	97 %
NMVOC	100	6	59	49	43	12 %
PM_{10}	50	91	1 692	1 691	1 601	5 %
CO	500	207	525	485	278	43 %

Note: * Reported EPER emissions divided by estimated emissions above thresholds in %.

Source: Based on EPER, 2006 and Platts, 2006.

have a relatively high uncertainty. The estimated emissions used to gap fill the EPER data set are based on the information on installed abatement techniques available within the Platts WEPP Database. No information is available about the quality of these data in terms of the characterisation of the abatement installed or the completeness of this data set in this respect. The methodology also uses various parameters (e.g., emission factors) reflecting average values at EU level but which might not be correct for specific facilities.

The apparently lower levels of emissions reported for CO and NMVOC are consistent with the findings of the EPER Review 2004 report (EC, 2007a) which found that, with some noted exceptions, emissions of these pollutants in the EPER database are generally significantly lower than the emissions reported by countries to the NEC Directive (EC, 2001b) and the UNECE LRTAP Convention (UNECE, 1979) and its protocols for the industrial combustion sectors.

Based on the above, it was concluded that the approach used does not provide the necessary level of reliability to allow use of the estimating technique in the further assessment of the emission reduction potential for the pollutants CO, NMVOC and PM_{10}. Had this method been applied for these pollutants, conclusions would have been drawn on the basis of data derived using assumed emission factors, rather than using predominantly actual reported emissions (as is the case for NO_X and SO_2). Therefore only reduction potentials for NO_X and SO_X were further assessed in the study.

3.3 Full implementation of BREF AELs

Figures for estimated reduction potential for NO_X and SO_2 reflecting the implementation of BREF AELs are presented in Table 3.2, and by fuel in Figure 3.1.

The following results are observed:

- Emissions of NO_X from the large combustion plants, as included in the EPER 2004 data set, would have been nearly 60 % lower if all plants had been performing according to the 'upper end of BAT' AELs in 2004;
- In the more strict interpretation of the BAT described in the LCP BREF ('lower end of BAT' AELs) the emissions could have been a factor of six lower in 2004 than the emissions reported under EPER;
- For SO_2, introducing BREF AELs in all facilities would have decreased emissions from the large combustion plants in this study to an even larger extent. For 2004, the emissions would have been more than a factor of five lower for the 'upper end of BAT' AELs and about a factor of thirty for the 'lower end of BAT' AELs;
- By far the largest contributions to these decreases would follow the application of BREF AELs at coal- and lignite-fired large combustion plants.

Figure 3.2 presents the cumulative effects of first introducing 'upper end of BAT' AELs at the facilities having the highest potential to reduce emissions. It can be determined that introduction of BAT and associated BREF AELs for NO_X at 155 of the 450 facilities in 2004 would have produced 90 % of the total potential emission reductions. For SO_2, 90 % of the potential emission reductions would have been achieved in 2004 by full introduction of BREF AELs in 102 of the 450 facilities.

It should be noted that the analysis described above in the context of the BREF AELs (and that which follows with respect to the LCP Directive ELVs) is not aimed at identifying units or facilities that are

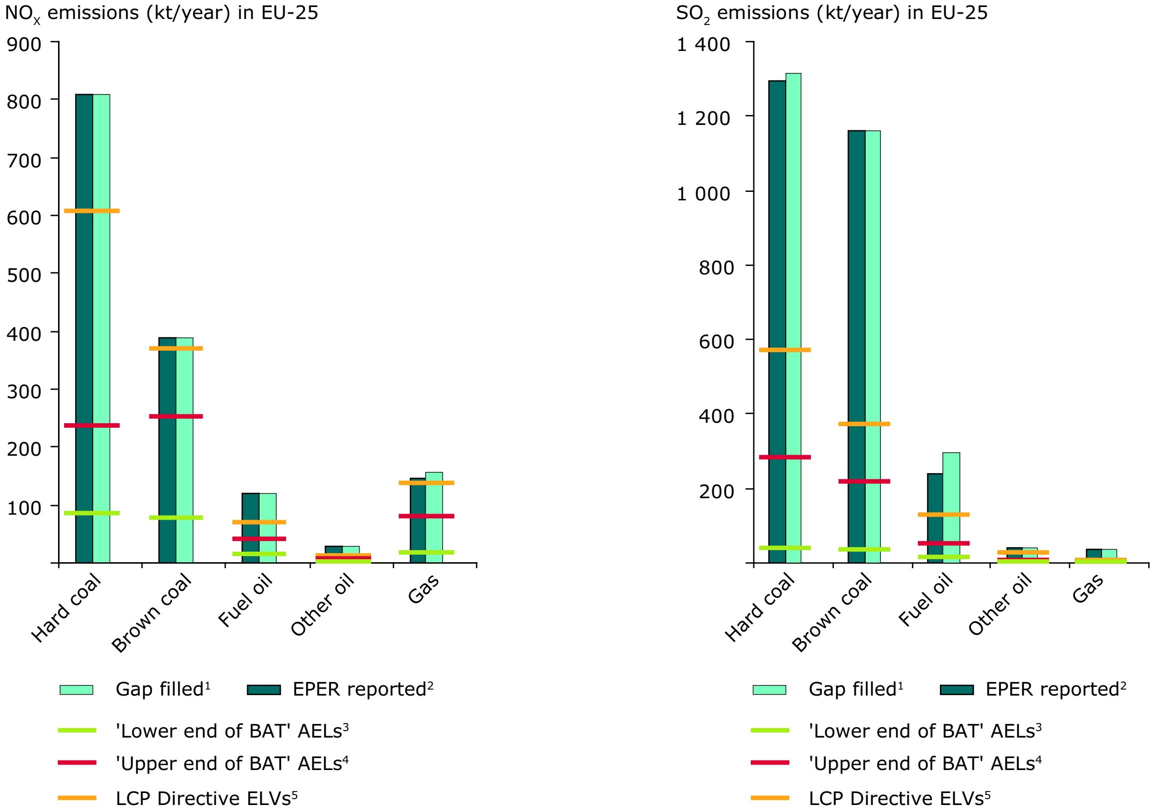
Table 3.2 Estimated emission reduction in 2004 through full introduction of BREF AELs in LCPs (for the selected set of 450 facilities)

Pollutant	2004 EPER emissions ([18])	Estimated emission reduction potential (kt/year) ([19])			
		'Upper end of BAT'		'Lower end of BAT'	
		kt	%	kt	%
NO_X	1 506	884	– 59 %	1 308	– 87 %
SO_2	2 853	2 287	– 80 %	2 754	– 97 %

Source: Based on EPER, 2006 and Platts, 2006.

([18]) Including estimated facility emissions for 2004 where these were not reported in EPER.
([19]) For plants that have reported emissions below the estimated emissions corresponding to the BREF AELS, no emission reduction potential is assumed.

Figure 3.1 Reported EPER emissions compared with estimated 'as is' emissions and estimated emissions for 2004 corresponding to BREF AELs and LCP Directive ELVs for NO_x and SO_2 in kg (450 facilities, 1 482 combustion installation units)



Note: [1] 'As is' (gap-filled) emissions for 2004.
[2] Emissions reported under the EPER decision for the selected facilities for 2004.
[3] Emissions that would have resulted from the full implementation of BAT corresponding to the lower end of the BREF AELs in 2004.
[4] Emissions that would have resulted from the full implementation of BAT corresponding to the upper end of the BREF AELs in 2004.
[5] Emissions that would have resulted from the at least full implementation of the LCP Directive ELVs in 2004.

Source: Based on EPER, 2006 and Platts, 2006.

not complying with specific legislation or with the LCP BREF. It merely provides an estimate of what emissions would have occurred at the EU level in 2004 had all units and facilities had emissions that corresponded to the emission performance in line with the BREF AELs and the LCP Directive ELVs respectively.

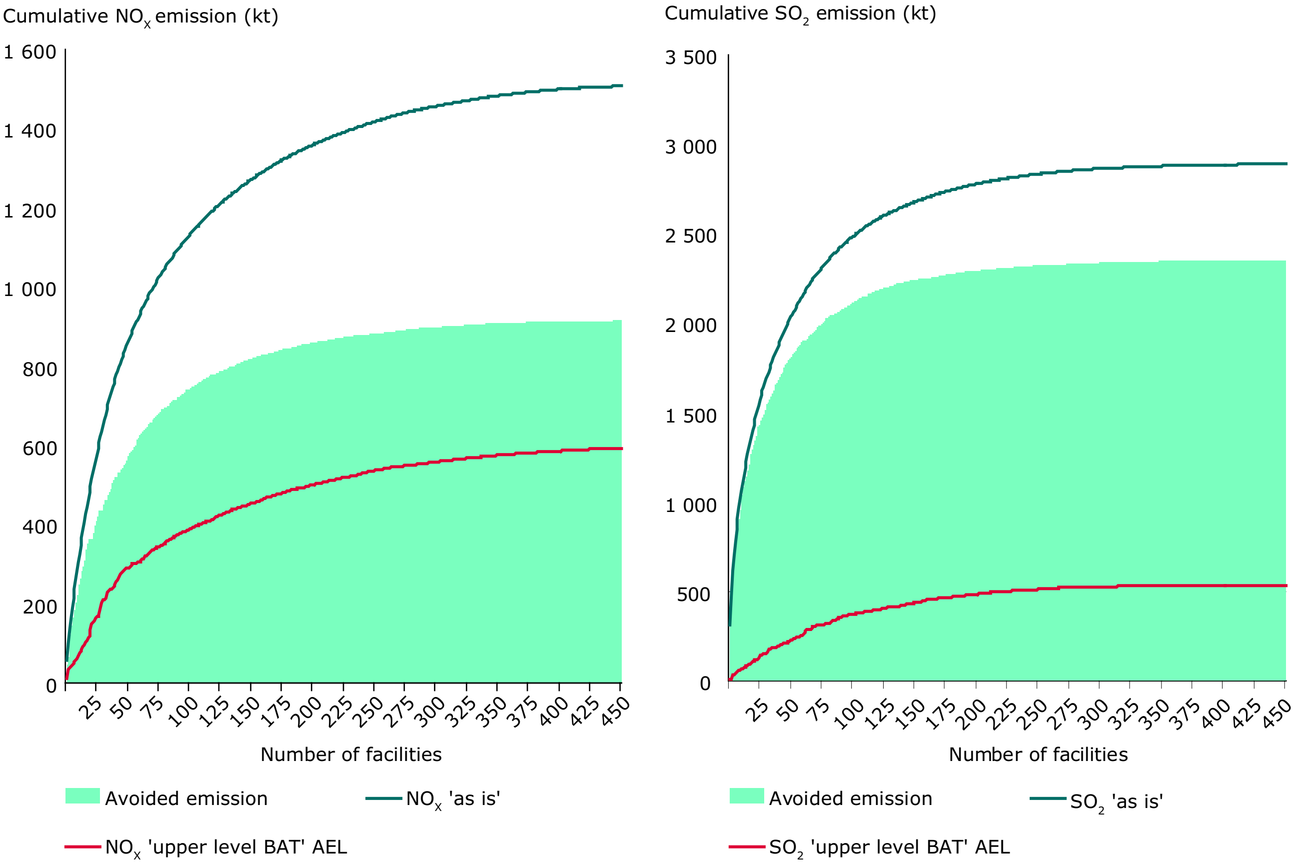
Although the analysis is performed at the level of individual facilities, care should also be taken to only use the results at an aggregated level. A number of assumptions as described in the methodology apply for the averaged group of large combustion plants and not necessarily for individual units or facilities. Hence, although individual facilities might not be reflected correctly in the analysis of this study, the conclusions of the work are considered valid at an aggregated level, where deviations from the averaged behaviour at individual facilities or units will average out.

3.4 Full implementation of LCP Directive ELVs

'As is' NO_x and SO_2 emissions from the 450 facilities included in this study are considerably (20 % and 61 % respectively) above the estimated emissions corresponding to the full implementation of the LCP Directive ELVs in these facilities ([20]) in 2004.

([20]) Under LCP a number of plants have opted out (limited life-time derogation) or will have derogations via the Accession Treaties for the 'new' Member States (EU-10+2). For NO_x, a more stringent ELV will apply after 2016 for coal fired plants > 500 MW_{th}. The analysis in this report does not take these elements into account.

Figure 3.2 Cumulative effect of introducing BAT upper-level AELs in LCPs



Source: Based on EPER, 2006 and Platts, 2006.

Since the ELVs are less stringent than the BREF AELs, the difference between the 'as is' emissions and the possible potential benefit of applying the LCP Directive's ELVs is smaller than in the case of the BREF AELs. In Table 3.3 the emission reduction potential of achieving the LCP Directive ELVs is demonstrated.

In order to verify these conclusions for implementation of LCP Directive ELVs, an alternative method was used to assess the estimated 'as is' 2004 emissions versus the emissions consistent with the LCP Directive ELVs.

Many facilities have reported emissions of both CO_2 and SO_2. With knowledge of the distribution of fuel utilized by the units within each facility, the ratio between the reported emissions for these two pollutants can be used to calculate an 'effective' sulphur content of the fuels and, in this way SO_2 concentrations in the flue gases can be estimated. The CO_2 to SO_2 ratio in the flue gases can be used

Table 3.3 Estimated emission reduction through full implementation of LCP Directive ELVs in LCPs (for the selected set of 450 facilities)

Pollutant	2004 EPER emissions ([21])	Estimated emission reduction potential at full implementation of LCP Directive ELVs in 2004 (kt/year)	
		kt	%
NO_x	1 506	308	– 20 %
SO_2	2 853	1 743	– 61 %

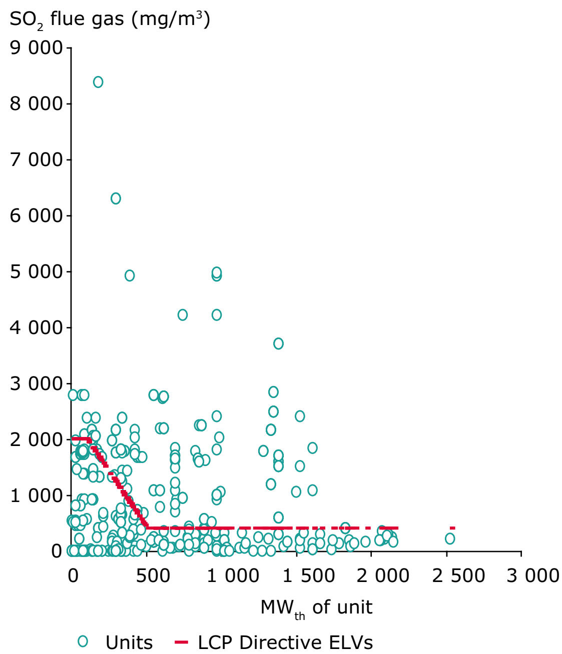
Source: Based on EPER, 2006 and Platts, 2006.

([21]) Including estimated facility emissions for 2004, where these were not reported in EPER.

to estimate the apparent S to C ratio in the fuel (corrected for abatement installed). From this the SO_2 concentrations in the flue gases can be calculated and compared with the LCP Directive ELVs. The results of this exercise for coal-fired combustion plants are presented in Figure 3.3 as unit-specific sulphur dioxide concentrations in the flue gases. Comparison with the LCP Directive ELVs shows that in a number of coal-fired power plants the emissions are higher than the emissions corresponding to the LCP Directive ELVs.

The observations shown in Figure 3.3 are thus consistent with those of Figure 3.1.

Figure 3.3 Estimated SO_2 flue gas concentrations versus MW_{th} of coal-fired Platts WEPP Database units identified in relation to LCP Directive ELVs



Source: Based on EPER, 2006; Platts, 2006 and EC, 2001a.

3.5 Implied emission factors from EPER reporting

As an additional check to verify the conclusions drawn from the analyses above, a separate verification exercise was performed involving the derivation of a frequency distribution of implied emission factors from EPER data and subsequent comparison with other information sources.

The fuel combusted at the unit level of facilities was estimated on the basis of the allocated CO_2 emissions and the fuel type as identified in the Platts WEPP Database (see Section 2.3). Since for all facilities NO_X emission reporting is available, and most facilities have also reported SO_2 emissions (if these are above the thresholds), implied emission factors for SO_2 and NO_X for these facilities can be calculated (Figure 3.4).

When evaluating the frequency distribution of the implied emission factors, it appears that for both NO_X and SO_2 many of the facilities have higher emission rates than the ones associated with BAT:

- For NO_X, emission factors calculated from BREF AELs are generally of the order of 20–200 g/GJ, depending on fuel and plant capacity, whereas many implied emission factors are in the range above 50–400 g/GJ;

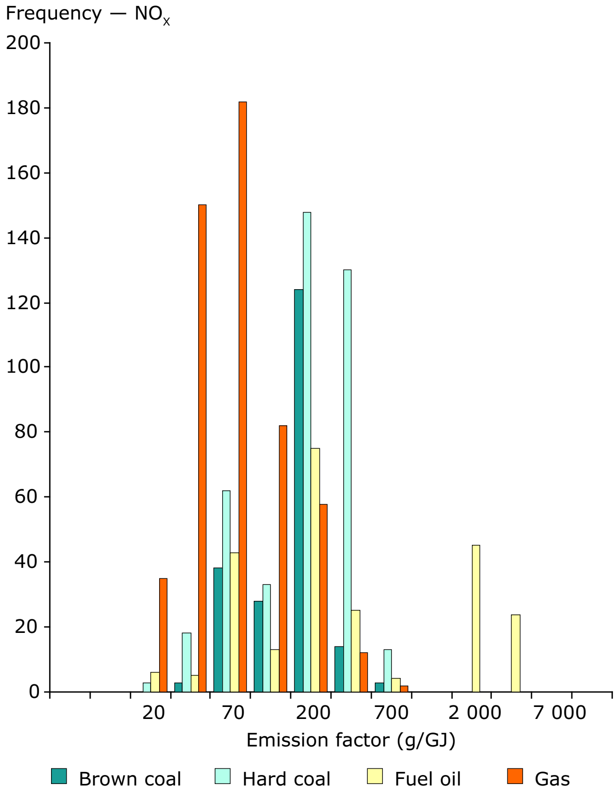
- For SO_2, emission factors calculated from BREF AELs are of the same order of magnitude as was noted for NO_X, but many observed implied emission factors are above 100, and some are even above 1 000 g/GJ. More than 50 LCPs show implied emission factors higher than 1 000 g/GJ, whereas the BAT emission factors for this pollutant are generally in the order of 3–180 g/GJ. Emission reduction measures for these relatively few facilities would decrease the overall LCP emissions considerably.

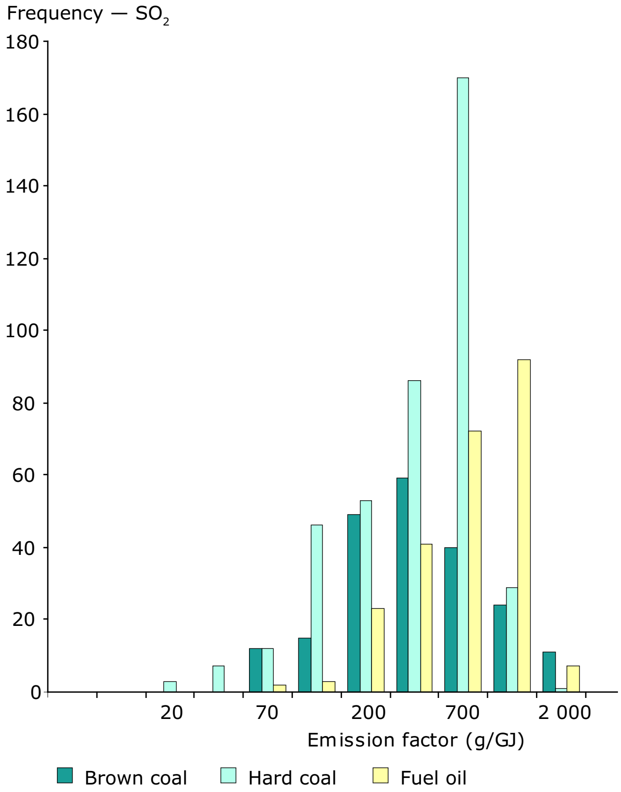
The frequency distribution of NO_X implied emission factors is very similar to that reported by Pulles and Heslinga (2004). These authors derived facility-level implied emission factors for data reported to the Dutch emissions inventory in the period 1990 to 1996, based on NO_X and CO measurements at individual plants.

The frequency distributions of implied emission factors for both NO_X and SO_2 also show consistency with emission factors available in the EMEP/CORINAIR Guidebook (EMEP/CORINAIR). From this it is concluded that the approach used could provide informative results for the total ensemble of facilities at an EU-25 level.

The variability of the implied emission factors is nevertheless quite large. This may lead to considerable methodological-derived uncertainty at the level of individual facilities and/or in small countries having a low number of facilities. This uncertainty is caused partly by the fact that some facilities will already have implemented abatement techniques or introduced lower emission technologies, while others have not done so. The EPER data set does not provide information on the level of abatement already implemented at individual facilities.

Figure 3.4 Frequency distribution (vertical) by fuel of implied emission factors (x-axis, g/GJ) for NO_X (left) and SO_2 (right) in the selected EPER facilities as reported in 2004





Source: Based on EPER, 2006 and Platts, 2006.

When comparing the frequency distributions of implied emission factors (Figure 3.4) to the emission factors corresponding to the BREF AELs, it can however be concluded that the full introduction of BREF AELs could have decreased the emissions for these pollutants considerably in 2004 at EU-25 level. This is in line with the study results concerning the emission reduction potential for SO_X and NO_X (Section 3.3).

4 Uncertainty analysis

4.1 Introduction

In this study, the calculations to estimate emissions involve a number of assumptions, each of which has associated uncertainties. These uncertainties produce further uncertainties in the estimates of overall resulting emissions. This chapter presents the results of two different approaches used to ascertain how the uncertainties associated with the assumptions involved in the calculations affected the overall emission estimates:

1. a sensitivity analysis (Section 4.2); and
2. a Monte Carlo analysis (Section 4.3).

It should be noted that quantitative information on potential errors and uncertainties in the Platts WEPP Database and the EPER data sets is not available. An assessment of their respective contributions to the uncertainty of the overall result is therefore not possible. For this reason, a full uncertainty analysis and overall confidence interval for the estimates of the potential emission reduction cannot be determined.

4.2 Sensitivity analysis

In a sensitivity analysis, one or two crucial assumptions in the procedure are modified, either by modifying the value of a certain parameter or by replacing one procedure by another. Three important assumptions are subjected to a sensitivity analysis in this section:

- the attribution of fuel to the different units within each facility;
- the way the flue gas volumes are estimated; and
- the influence of gas turbines .

4.2.1 *Fuel attribution over the different units within each facility by assuming equal operation times*

The fuel attribution over the different units within a facility is performed by attributing the reported CO_2 emissions in the EPER 2004 data set to the identified Platts units within the EPER facilities (Section 2.2). Ideally, this should be done based on an estimate of the operational times for each of the units of an EPER facility. Since neither the Platts WEPP Database nor any other data set evaluated provides the actual operation times for the individual units, an assumption had to be made concerning these operation times.

Within the analysis presented in the previous chapter, the assumption was made that all units within each facility have equal operation times. As a result, the reported CO_2 emissions in the EPER 2004 data set are attributed proportionally according to the thermal capacities of each unit within the facility.

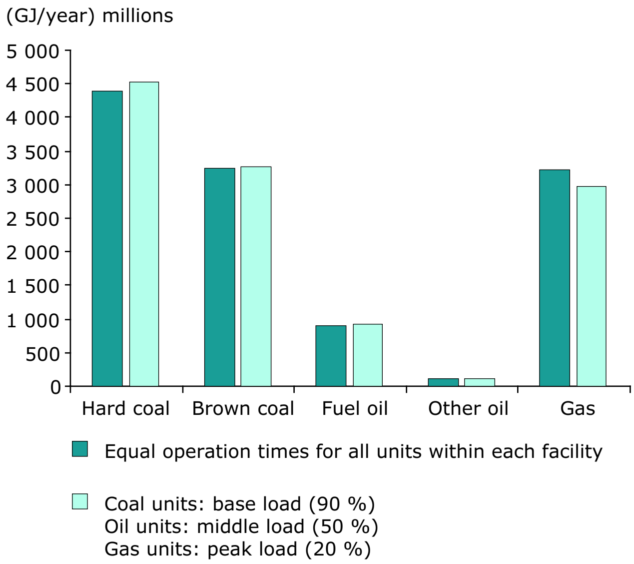
Different assumptions could have been made for the operation times. The alternative assumption used in the sensitivity analysis is derived from the observation that solid fuels are typically used in base load facilities, whereas natural gas is typically used in peak load units; hence coal units will use about twice as many operating hours as middle load units (oil) and about four times as many as peak load units on gas (Table 4.1).

The results of the sensitivity analysis are presented in Figure 4.1. The chart illustrates that relatively higher (about 5 %) use of solid fuels (coal and brown coal) and lower (– 6 %) use of natural gas occurs. Since the emission factors for solids are generally higher than those for liquid and gaseous fuels, this higher coal use will result in higher total estimated emissions. For all three cases analysed ('as is' , introduction of the BREF AELs and introduction of LCP Directive ELVs), this will result in only a slight increase in the estimated emission levels for coal and

Table 4.1 Assumed characteristic operation times

Fuel	Usage %	Operation time (hours)
Hard coal	90 %	7 884
Brown coal	90 %	7 884
Fuel oil	50 %	4 380
Other oil	50 %	4 380
Gas	20 %	1 752

Figure 4.1 Sensitivity of estimated fuel use (in GJ/year) to assumptions of operation times for units within facilities



Source: Based on EPER, 2006 and Platts, 2006.

a slight decrease of estimated emission levels for gas-fired combustion.

Based on this sensitivity analysis it is concluded that the assessment results presented in the previous chapter are not very sensitive to the assumptions made of operation times.

4.2.2 *Flue gas volume*

Depending on combustion conditions, the flue gas volumes associated with the combustion of fossil fuel can vary quite substantially (see Annex D).

The consequences of the assumption used for the fuel-specific flue gas volumes were evaluated by comparing emission estimates obtained using an empirical approach (as was used to obtain the results in Chapter 3) with the results obtained by using a stoichiometric approach (details provided in Annex D).

Figure 4.2 presents the results obtained using a stoichiometric approach. When comparing these to the results shown in Figure 3.1, it can be concluded that the application of a stoichiometric approach actually increases the estimate of the potential benefits that could be obtained. Within the methodology, flue gas volumes are only used to transform the ELVs and AELs from concentration to mass flow values. Therefore the effect of changing the assumption of flue gas volumes is only apparent on the estimated emissions corresponding to the BREF AELs and the LCP Directive ELVs (lines in the graphs).

It can therefore be concluded that the estimated emission reduction potential is sensitive to the flue gas volume assumption used. The results obtained by applying different assumptions concerning the flue gas volumes are however similar, and hence largely independent of the exact assumption used with respect to the flue gas volumes.

4.2.3 *Influence of gas turbines*

The results presented in Section 3 are based on the assumption that all gas-fired plants employ boiler technology.

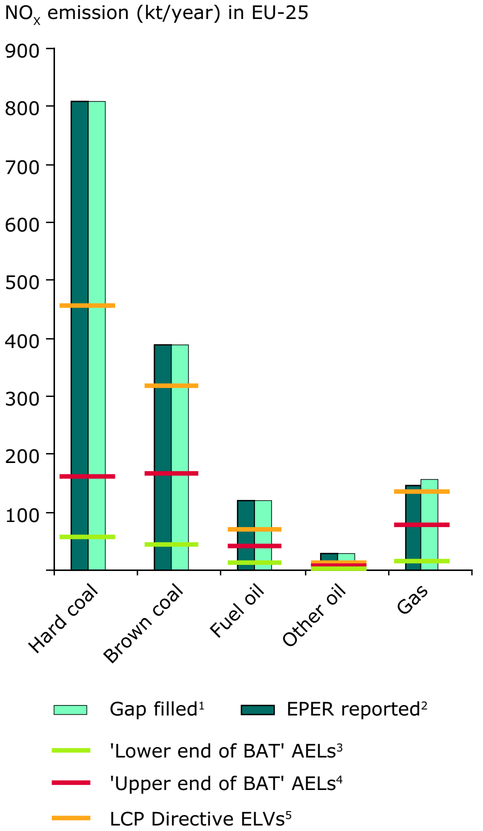
This assumption has also been made for gas-fired power plants, although in reality a significant share of gas-fired power plants in this study are equipped with gas turbines (Table C.1 in Annex C) shows the numbers of units and respective gas turbine technologies identified from the Platts WEPP Database). However, gas turbines directly burn gas with a large excess of air and therefore use an air to fuel ratio larger than that of conventional boiler-type burners. Where it is usual for gas boilers to use 3 % oxygen, the gas turbines operate typically at 15 % oxygen.

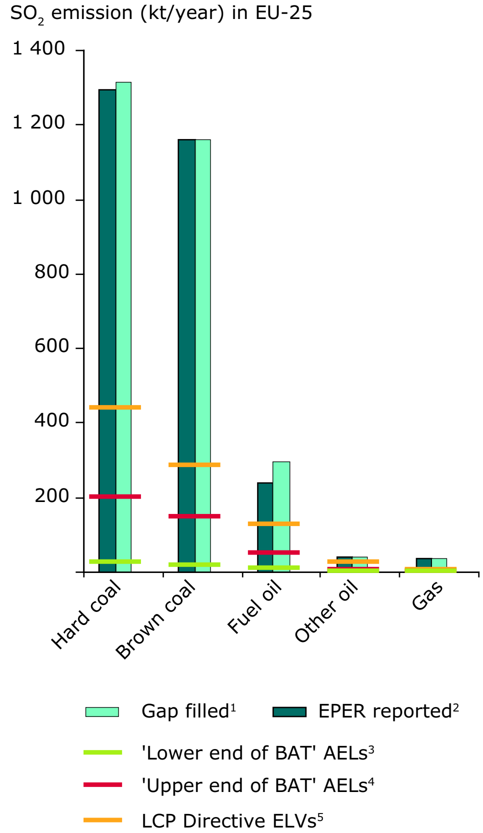
Differences in turbine technology have not been taken into account — the following were considered outside the scope of this study:

- the lower NO_X emission factor for gas turbines compared to gas boilers in general caused by the larger excess of air in gas turbines, which results in a lower estimate of emissions following the gap filling procedure used to estimate 'as is' emissions; and

- the BAT described in the BREF for both groups of LCP types. The LCP BREF sets AELs at 15 % and 3 % oxygen respectively for turbine-type and boiler-type burners. The LCP Directive ELVs are set similarly. This has a direct influence on the flue gas calculations and as a result on the emission factor calculations. For gas turbines, the higher O_2 content increases flue gas volumes by a factor of 2.5–3 and will thus influence the emission factors corresponding to the BREF AELs. For any given AEL, varying oxygen levels can approximately double the emission factor. Taking into account the fact that the BREF AEL ranges for NO_X are slightly lower for the turbines than for the boilers (20–90mg/

Figure 4.2 Emission estimates in kg using carbon stoichiometry to calculate the assumed specific flue gas volumes (as a comparison to Figure 3.1 which shows estimates made using the empirical approach) (450 facilities, 1 482 combustion installation units)





Note: [1] 'As is' (gap-filled) emissions for 2004.
[2] Emissions reported under the EPER decision for the selected facilities for 2004.
[3] Emissions that would have resulted from the full implementation of BAT corresponding to the lower end of the BREF AELs in 2004.
[4] Emissions that would have resulted from the full implementation of BAT corresponding to the upper end of the BREF AELs in 2004.
[5] Emissions that would have resulted from the at least full implementation of the LCP Directive ELVs in 2004.

Source: Based on EPER, 2006 and Platts, 2006.

Nm^3 versus 50–100 mg/Nm^3) the estimated emissions from a plant employing pollutant abatement methods/techniques corresponding to the BAT described in the LCP BREF, will be approximately a factor of 2 higher for a turbine than for a boiler.

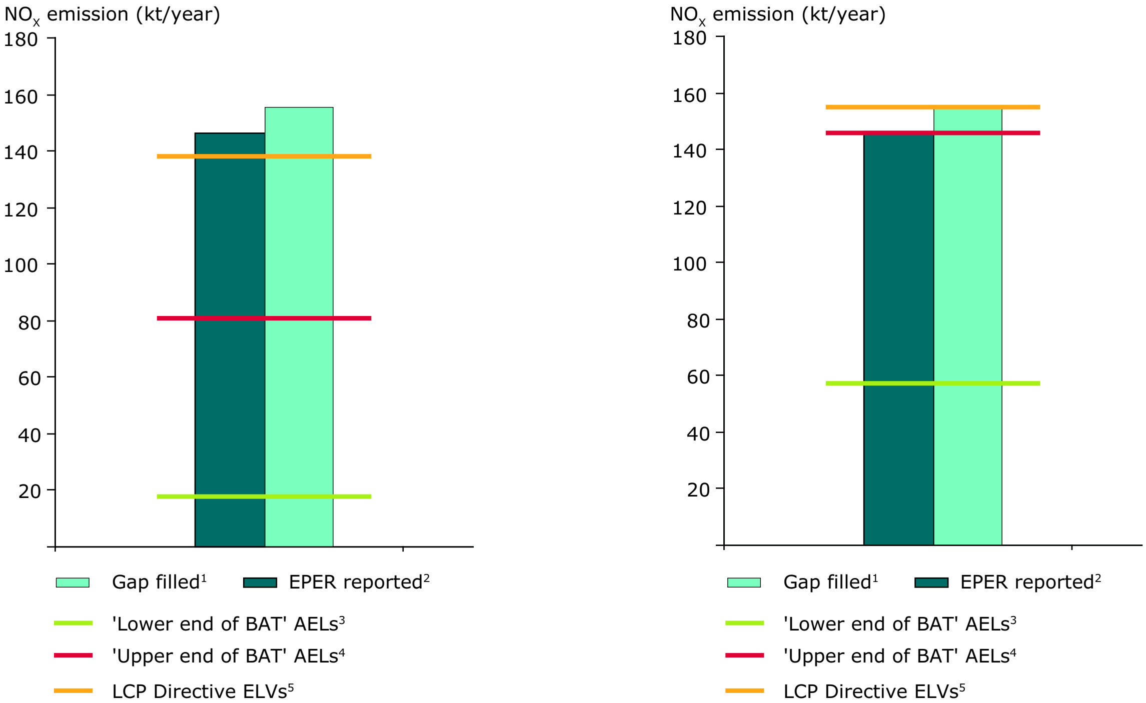
To understand the effect on the estimated NO_X emissions of the difference in emission factors between the gas boilers and gas turbines, a 'sensitivity' analysis using two sets of gas NO_X emission factors was performed.

Figure 4.3 shows the effect, in terms of NO_X emissions, of assuming all gas-fuelled combustion plants in the study are either (i) gas boiler or (ii) gas turbine types. With the assumption that all gas-fired units are gas turbines, the emission reduction potential for NO_X corresponding to the upper BAT level and corresponding to the LCP Directive ELVs is removed. The evaluation shows that the relatively small potential for the reduction of NO_X emissions in gas-fired plants would probably disappear. It is hence concluded that this is a sensitive parameter in terms of the results for the gas-fired power plants. However, in the context of the whole study, emissions of NO_X and SO_2 from gas-fired plants are small compared to those arising from coal-fired plants and it is therefore considered relatively insignificant in the context of this study.

4.3 Monte Carlo analysis

In a Monte Carlo analysis, the effects of uncertainties associated with parameter values are assessed

Figure 4.3 Difference of calculated BAT and LCP emissions for NO_x assuming all gas-fired power plant units are boiler types (left) and assuming all are turbine types (right)



Note: [1] 'As is' (gap-filled) emissions for 2004.
[2] Emissions reported under the EPER decision for the selected facilities for 2004.
[3] Emissions that would have resulted from the full implementation of BAT corresponding to the lower end of the BREF AELs in 2004.
[4] Emissions that would have resulted from the full implementation of BAT corresponding to the upper end of the BREF AELs in 2004.
[5] Emissions that would have resulted from the at least full implementation of the LCP Directive ELVs in 2004.

Source: Based on EPER, 2006 and Platts, 2006.

by a form of 'gambling'. For each of the uncertain parameters, a probability distribution function is assumed and a large number of analysis runs are performed, each using a randomly drawn value from defined probability distribution functions for each of the parameters. The final results generated from the large number of runs are subsequently summarised in terms of a probability distribution function of the final calculation result.

The Monte Carlo simulations described in this chapter aimed to assess the uncertainties associated with two different assumptions:

1. the assumption concerning the value of the CO_2 emission factors (Table 2.4). The IPCC Guidelines indicate a range for each of the fuel-dependent CO_2 factors. For the analysis presented in Chapter 3, the population average of these ranges was used. If, however, the assumed emission factor does not reflect the reality at plant level, the analysis will estimate an incorrect fuel use and hence the calculated emissions will differ from those that would occur at plant level in reality.

2. the assumption concerning the efficiency of power plants (Table 2.2). If the underlying assumption concerning plant efficiency is incorrect, the attribution of individual units to thermal capacity classes may also consequently be incorrect. This will result in the wrong emission factors being applied and hence an inaccurate estimate of the difference between the reported emissions and the 'upper end of BAT' requirements.

The uncertainties arising from these two assumptions were assessed with respect to their influence on the NO_x emission estimate corresponding to the introduction of BREF AELs ([22]).

([22]) For SO_2 a similar assessment can be made. However, results of such an analysis are not presented.

The results are presented as probability distributions of the estimated emissions occurring from full introduction of BREF AELs ('upper end of BAT' AELs). The mean emissions estimate from the Monte Carlo analysis runs is also expressed as the percentage of the emissions that would remain at full introduction of the 'upper end of BAT' AELs.

The Monte Carlo analyses were performed with the MS Excel add-on '@Risk' (version 4.5 ([23]), using a Latin Hypercube sampling strategy. The number of iterations was set to 500. In the Monte Carlo uncertainty analysis, the values of the parameters studied can be sampled for the total number of units having the same fuel. For every iteration, the parameters are sampled once and these values are then applied to all the units. This reflects the uncertainty distribution of the mean value of the parameter. This means that these sampled parameters for all units are fully correlated.

Another approach is to use fully uncorrelated values. This means that, per iteration, the parameter is sampled independently for each unit. This reflects the (natural) variability of the parameter. The effect of the parameter variability would be considerably smaller since the large number of units (over 1 000) would cause averaging out of the effect.

For the influence of the CO_2 emission factors on the total uncertainty (Section 4.3.1) both approaches (uncorrelated and correlated) were used. In the uncertainty analysis concerning the effect of the fuel efficiencies only the uncorrelated analysis was applied.

4.3.1 Monte Carlo analysis: CO_2 emission factors

The uncertainty ranges as given in the 2006 IPCC Guidelines for the fuel-dependent emission factors are used to describe the (lognormal) probability distributions for these emission factors.

a) Fully correlated sampling

Fully correlated sampling of the CO_2 emission factors was used to analyse the subsequent effects on the NO_X emission estimates. The results are presented in Table 4.2. The results are based on the assumption that the values used for the CO_2 emission factors for each fuel type are uncertain, in the sense that the exact value to be applied for each unit across all facilities is not known. For every Monte Carlo iteration, the probability function is sampled for each fuel type and the sampled value is then assumed to be the same for all units with the same fuel type (i.e. fully correlated sampling).

The results indicate that, with respect to the possible range of fuel-specific CO_2 emission values:

- the total NO_X emission reduction achievable by applying the upper end of BREF AELs to all 1 482 units within the 450 facilities included in this study would vary between 901 and 935 kt in 2004 (90 % confidence interval);

Table 4.2 Monte Carlo 90 % confidence intervals for the theoretical emission reduction potential of NO_X resulting from the introduction of techniques corresponding to 'upper end of BAT' — correlated sampling of CO_2 emission factors

Fuel	Avoided emissions			
	5-%ile	Mean value		95-%ile
	kt	kt**	% of 'as is'	kt
Hard coal	571.3	580.7	27.7	589.4
Brown coal	154.2	167.6	57.2	182.0
Fuel oil	72.7	73.3	39.3	73.9
Other oil	19.6	19.7	33.3	19.8
Gas	76.0	77.4	52.1	78.6
All fuels*	901.2	918.7	39.0	935.4

Note: *Since percentiles cannot be directly summed for the different fuels, the total 5 and 95 %iles for all fuels together are not equal to the sum of the corresponding percentiles of each separate fuel.

**Due to the deviations from normality in some probability distribution functions, the Monte Carlo analysis can result in slightly different mean values when compared to other tables in the report, where stochastic variations are not applied.

Source: Based on EPER, 2006 and Platts, 2006.

([23]) http://www.palisade-europe.com/.

Table 4.3 Monte Carlo 90 % confidence intervals for the theoretical emission reduction potential of NO_x resulting from the introduction of techniques corresponding to 'upper end of BAT' — uncorrelated sampling of CO_2 emission factors (influence of unit-level emission factor variability)

Fuel	Avoided emissions			
	5-%ile	Mean value		95-%ile
	kt	kt**	% of 'as is'	kt
Hard coal	580.1	580.7	27.7	581.3
Brown coal	166.3	167.6	57.2	168.9
Fuel oil	73.2	73.3	39.3	73.4
Other oil	19.6	19.7	33.3	19.7
Gas	77.2	77.4	52.1	77.6
All fuels*	917.2	918.7	39.0	920.1

Note: *Since percentiles cannot be directly summed for the different fuels, the total 5 and 95 %iles for all fuels together are not equal to the sum of the corresponding percentiles of each separate fuel.

**Due to the deviations from normality in some probability distribution functions, the Monte Carlo analysis can result in slightly different mean values as compared to other tables in the report, where stochastic variations are not applied.

Source: Based on EPER, 2006 and Platts, 2006.

- the largest contribution to the uncertainties is caused by the uncertainties in the CO_2 emission factors of brown coal and hard coal.

b) Uncorrelated sampling

In reality, the CO_2 emission factors in different facilities with the same fuel type are uncorrelated. The probability function defined in the IPCC Guidelines is an approximation of the real-world CO_2 emission factor distribution in large combustion units per fuel group. This function is used in the Monte Carlo analysis with uncorrelated sampling.

The sampled value of the emission factor in one specific unit will be different to that in all others, but will still lie within the same probability distribution function. So rather than sampling the probability function for each fuel and then applying it to all units with the same fuel, a separate

Table 4.4 Monte Carlo 90 % confidence intervals for the theoretical emission reduction potential of NO_x resulting from the introduction of techniques corresponding to 'upper end of BAT' — uncorrelated sampling of the assumed thermal efficiency

Fuel	Avoided emissions			
	5-%ile	Mean value		95-%ile
	kt	kt***	% of 'as is'	kt
Hard coal	579.8	580.7	27.7	580.8
Brown coal	167.4	167.6	57.2	167.9
Fuel oil	73.3	73.3	39.3	74.0
Other oil	19.0	19.7	33.3	19.8
Gas*	–	77.4	52.1	–
All fuels**	917.5	918.7	39.0	919.1

Note: *Since the BREF AELs for gas are not dependent on size of the boiler, no influence of the efficiency estimate for this fuel is observed.

**Since percentiles cannot be directly summed for the different fuels, the total 5- and 95-%iles for all fuels together are not equal to the sum of the corresponding percentiles of each separate fuel.

***Due to the deviations from normality in some probability distribution functions, the Monte Carlo analysis can result in slightly different mean values as compared to other tables in the report, where stochastic variations are not applied.

Source: Based on EPER, 2006 and Platts, 2006.

sample was drawn for each and every single unit (i.e. uncorrelated sampling). Since in this case the variability of the values will largely average out, it was expected that a lower sensitivity of the result to this assumption would be observed and this indeed is what was observed as presented in the Table 4.3.

Conclusion

Based on the results of the correlated and uncorrelated analyses, the uncertainty inherent in the CO_2 emission factors is judged to have only a limited impact on the final emission reduction potential conclusions of the study.

4.3.2 Power plant efficiency

Power plant fuel efficiencies were assumed to have a normal distribution centred around the efficiency values used in the main analysis of the study (Section 2.3.2) and with a standard deviation of 5 %. Table 4.4 shows the frequency distributions of the emission reduction potential of NO_X corresponding to the 'upper end of BAT' using an uncorrelated Monte Carlo analysis for the power plant unit efficiencies.

No dependence was obtained for natural gas, simply because the BREF AELs for this fuel are not size dependent. A change in the efficiency value for individual units will therefore not have any influence on the resulting emission reduction potential.

Based on the 90 % confidence intervals, it can be concluded that the result in this case is largely independent of the assumptions concerning the value of the power plant efficiencies. The frequency distributions of the emission reduction potential do not differ by more than a few percent of the mean value.

5 Conclusions

The conclusions are based on the analysis of 450 EPER facilities, which cover in total more than 70 % of the SO_2 and NO_X emissions from the LCPs included in EPER. The study therefore covers 39 % and 14 % respectively of the total EU-25 emissions reported for these pollutants for the year 2004 (EEA, 2008).

5.1 Applicability of the method

By combining emission data from the EPER 2004 data set with information on the fuel types used in individual large combustion units, the fuel utilised in each of the individual facilities could be estimated using the reported CO_2 emissions. This approach could be used with 450 of the 1 268 combustion facilities (having the main activity 1.1 'Combustion Installations > 50 MW') in the EPER 2004 data set.

From the estimated fuel use and the reported NO_X and SO_2 emissions, implied emission factors for these pollutants could be derived. The frequency distribution of observed NO_X emission factors is consistent with an earlier study (Pulles and Heslinga, 2004). The frequency distributions of implied emission factors for both NO_X and SO_2 also show consistency with emission factors available in the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2007).

From this it is concluded that the approach used could provide informative results for the total ensemble of facilities. However, the variability of emission factors is quite large, which may still lead to considerable uncertainties at the level of individual facilities and/or in small countries having a low number of facilities. This uncertainty is partly caused by the fact that some facilities will already have implemented abatement techniques or introduced lower emission technologies, while others have not done so. The EPER data set does not provide information on the level of abatement already implemented at individual facilities.

The EPER does not contain information beyond general data on the activity type and location of facilities and their respective emissions. Policy-relevant assessments based on EPER data would be significantly facilitated if data concerning such features as e.g. capacity, fuel type, emission factors used, (abatement), techniques installed were available in EPER. This study shows that such additional information would have made the data in the EPER reporting process very useful in assessing the implementation of environmental legislation.

5.2 Completeness of EPER reporting

The gap-filling procedure developed allows an assessment of the completeness of EPER reporting by individual facilities for the pollutants included in this report. Results of this analysis (Table 3.1) showed that reporting for CO_2, NO_X and SO_2 is rather complete. In contrast, emission reports for CO, NMVOC and PM_{10} might be missing for many facilities. It was estimated that, as a maximum, about two thirds of the emissions of CO and PM_{10} are not reported, although they could be below the threshold for which reporting to EPER is required.

The apparently lower levels of emission reported for CO and NMVOC are consistent with the findings of the EPER Review 2004 report (EC, 2007a), which found that, with some noted exceptions, emissions of these pollutants in the EPER database are generally significantly lower than the emissions reported by countries to the NEC Directive and the UNECE LRTAP Convention for the industrial combustion sectors.

Based on this, it was concluded that the unavailability of emission reports for these pollutant emissions at many facilities does not provide the necessary level of reliability for CO, NMVOC and PM_{10} required to apply the method derived in this report. This would have led to conclusions being drawn on the basis of data derived from emission factors, rather than using predominantly actual reported emissions (as is the case for NO_X and SO_2) Therefore, only the reduction potentials for NO_X and SO_2 were assessed in the study.

5.3 Emission reduction potential of NO_X and SO_2

When estimating emissions using the emission factors associated with BREF AELs for NO_X and

SO_2, it appears that the emissions from LCPs could be reduced by a factor of two or more compared to currently reported emissions.

The following conclusions were drawn:

- the emissions of NO_X from the LCPs, as included in the EPER 2004 data set, would have been nearly 60 % lower if all plants would have been performing according to the 'upper end of BAT' AELs in 2004;
- in the more strict interpretation of the BAT described in the LCP BREF ('lower end of BAT' AELs) the emissions could have been a factor of six lower in 2004 than the emissions reported under EPER;
- for SO_2, the effect of introducing BREF AELs in all facilities would have decreased emissions from the large combustion plants included in EPER to an even greater extent. For 2004, the emissions could have been more than a factor of five lower for the 'upper end of BAT' AELs and about a factor of thirty for the 'lower end of BAT' AELs;
- introduction of BREF AELs for NO_X at 155 of the 450 facilities in 2004 would have resulted in 90 % attainment of the total potential emission reductions. For SO_2, 90 % of the potential emission reductions would have been achieved in 2004 from full introduction of BREF AELs in 102 of the 450 facilities;
- by far the largest contributions to these decreases would follow the introduction of BREF AELs at coal- and lignite-fired LCPs.

5.4 LCP Directive ELVs

The ELVs as defined in the LCP Directive are less stringent than the AELs defined in the BREF documents. The potential benefit of implementing the LCP Directive ELVs at all units within all facilities will therefore result in a lower emission reduction percentage (approximately one quarter for NO_X and two thirds for SO_2) compared to application of the BREF AELs.

5.5 Implied emission factors from EPER reporting

Implied emission factors were calculated for facilities that reported NO_X and SO_2 emissions under EPER for 2004. The distribution of the implied emission factors was consistent with emission factors available in the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2007).

Comparison of the frequency distributions of implied emission factors with derived emission factors corresponding to BREF AELs supports the significant emission reduction potentials at the EU-25 level, in line with the study results concerning the emission reduction potentials for NO_X and SO_2.

As an example, for SO_2 more than 50 LCPs show implied emission factors higher than 1 000 g/GJ, whereas the BAT emission factors for this pollutant are generally in the order of 3–180 g/GJ. Implementing emission reduction measures for these relatively few facilities would decrease the overall LCP emissions considerably.

5.6 Uncertainty

Quantitative information on the potential errors and uncertainties in the Platts WEPP Database and the EPER data sets is not available, and hence a full uncertainty analysis and overall confidence interval for the potential emission reduction estimates derived in this study cannot be determined.

Nevertheless, a limited uncertainty analysis performed shows that the results of the comparison of actual reported emissions with what would have been expected if BAT ('upper end of BAT' AEL) were fully introduced is rather insensitive to the main assumptions made in the analysis (including, e.g., the choice of CO_2 emission factors, the attribution of fuel to different units within each facility, the method in which flue gas volumes were estimated and the values assumed for the efficiency of power plant units). The methodology was, however, shown to be sensitive to the technology assumed for gas-fired plants (i.e. use of gas boiler or gas turbine technology). However, in the context of the whole study, emissions of NO_X and SO_2 from gas-fired plants are small compared to those arising from coal-fired plants.

It is clear that more Monte Carlo simulations could provide a more complete picture of the uncertainties and sensitivities associated with the approach used.

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Annex A Linking of EPER and Platts WEPP databases

An overview is provided in Table A.1 of the number of EPER facilities that were linked to electrical power plants listed in the Platts WEPP Database. The data in Table A.2 provides a further overview of fuel use as included in the Platts WEPP Database, the more general fuel type assigned for the purpose of this study, the number of EPER facilities linked to the different fuel types and the number of Platts units linked to the different fuel types and EPER facilities.

Table A.1 Overview of number of EPER facilities linked to electrical power plants listed in the Platts WEPP Database

Country	Number of EPER facilities linked to electrical power plants listed in the Platts WEPP Database
Austria	13
Belgium	17
Cyprus	3
Czech Republic	16
Denmark	18
Estonia	2
Finland	29
France	35
Germany	102
Greece	16
Hungary	10
Ireland	11
Italy	81
Latvia	2
Lithuania	4
Luxembourg	1
Malta	2
Netherlands	22
Poland	36
Portugal	9
Slovak Republic	4
Slovenia	3
Spain	33
Sweden	8
United Kingdom	51
Grand Total	528

Source: Based on EPER, 2006 and Platts, 2006.

Table A.2 Assigned fuel types to fuels reported in the Platts WEPP Database and number of units identified in the 450 EPER facilities of the EPER 2004 data set

Assigned fuel type (for the purpose of this study)	Platts fuel type	Number of EPER facilities linked to fuel type in Platts	Number of Platts units in selected EPER facilities linked to fuels
Hard coal	Anthracite and bituminous coal	3	8
	Anthracite or semi-anthracite coal	5	11
	Bituminous coal	147	370
	Bituminous coal and anthracite coal	3	4
	Sub-bituminous coal	5	14
Brown coal	Bituminous coal and lignite (brown coal)	7	10
	Lignite (brown coal)	41	182
	Lignite and bituminous coal	3	12
	Lignite and sub-bituminous coal	2	6
Fuel oil	Heavy fuel oil (Number 6 oil or bunker)	64	239
	Residual oil	1	1
Other oil	Diesel oil	8	22
	Distillate oil (also Number 2 oil and light fuel oil)	32	82
Gas	Natural gas	220	511
	Liquefied natural gas	2	10
Total*		450	1 482

Note: *Since the Platts WEPP Database contains information at the unit level, an EPER facility can consist of more than one unit and therefore can be assigned to more than one fuel type. Therefore, the total number of times that EPER facilities are assigned to Platts units (543) is higher than the total number of EPER facilities included in the evaluation.

Source: Based on EPER, 2006 and Platts, 2006.

Annex B Emission factors and abatement efficiencies

Table B.1 Fuel-dependent emission factors (g/GJ)

Pollutant	Source	Hard coal	Brown coal	Fuel oil	Other oil	Gas
NO_x	GAINS	292	183	195	129	93.3
SO_2	GAINS	765	1 361	1 350	228	0.68
CO	EMEP/CORINAIR	89.1	89.1	15.7	15.7	14.5
NMVOC	GAINS	4.92	7.78	3.70	3.24	1.58
PM_{10}	GAINS	1 203	3 254	16.0	1.91	0.10

Source: GAINS: weighted average over country-specific emission factors (IIASA, 2007a). EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2007).

Table B.2 Abatement techniques for NO_x control identified in the 450 EPER facilities with the Platts WEPP Database separation efficiencies

Abatement technique	Number of Platt units	Separation %		
		Applied in report**	'Lower end of BAT'	'Upper end of BAT'
Dry low-NO_x combustor	7	20 %		
Dry low-NO_x combustors	105	20 %		
EV (low-NO_x) burners	15	20 %		
Flue gas recirculation (particulate and NO_x control)	9*	35 %	20 %	50 %
Hybrid low-NO_x burners	22	20 %		
Low-NO_x burners	112	20 %		
Low-NO_x burners/burner management system	2	20 %		
Low-NO_x burners/flue-gas recirculation	1	20 %		
Low-NO_x burners/overfire air	3	20 %		
Low-NO_x burners/selective catalytic reduction	10	80 %		
Low-NO_x burners/staged combustion	2	20 %		
Low-NO_x combustors	0	20 %		
Overfire air (NO_x control methodology)	9*	40 %	10 %	70 %
Selective catalytic reduction	46	80 %		
SCR/Selective non-catalytic reduction	1	80 %		
SCR cold/high dust (after FGD system)	44	80 %		
SCR hot/low dust (between economiser and air preheater)	15	80 %		
SoLoNO$_x$ lean pre-mixed combustion	2	20 %		
Staged combustion	1	20 %		
Steam injection	22	20 %		
Water injection	8	20 %		
Not applicable	49	0 %		
None	28	0 %		

Note: *Techniques described in the LCP BREF. **The analysis uses the geometrical midpoint between upper and lower levels to estimate the effect of the abatement. Other techniques are assumed to have a default efficiency of 20 % for primary measures and 80 % for secondary measures.

Source: BREF LCP (EC, 2006); EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2007).

Table B.3 Abatement techniques for SO_2 control identified in the 450 EPER facilities with the Platts WEPP Database

Abatement technique	Number of Platts units	Separation %		
		Applied separation rate**	'Lower end of BAT'	'Upper end of BAT'
Atmospheric circulating fluidised bed boiler	19	50 %		
Circulating-bed FGD scrubber	2	50 %		
Compliance fuel that allows plant to meet applicable air quality standards	62	50 %		
Dry lime FGD scrubber	3	50 %		
Unspecified type of FGD scrubber*	28	95 %	90 %	99 %
Limestone injection into furnace with CaO activation	2	50 %		
Limestone injection	8	50 %		
Novel integrated desulphurisation scrubber (dry lime)	3	50 %		
Pressurized fluidized-bed combustor	2	50 %		
Spray dry lime FGD scrubber*	23	89 %	85 %	92 %
Spray dry FGD scrubber system	2	50 %		
Semi-dry lime FGD or other semidry gas cleaning system	5	50 %		
S NO_x flue gas cleaning system	2	50 %		
Sea water FGD scrubber*	1	92 %	85 %	98 %
Wet calcium carbonate FGD scrubber	6	50 %		
Wet FGD (unspecified)	1	50 %		
Wet lime FGD scrubber	12	50 %		
Wet lime/limestone FGD scrubber*	4	96 %	92 %	98 %
Wet lime/magnesium FGD scrubber	1	50 %		
Wet limestone FGD scrubber*	208	96 %	92 %	98 %
None or not applicable	618	0 %		

Note: * Techniques described in the LCP BREF.

**The analysis uses the geometrical midpoint between upper and lower levels to estimate the effect of the abatement. Other techniques are assumed to have a default efficiency of 50 %.

Source: LCP BREF (EC, 2006).

Table B.4 Abatement techniques with separation efficiencies for particulate matter (PM) control identified in the 450 EPER facilities with the Platts WEPP Database

Abatement technique	Number of Platts units	Applied separation rate*
Baghouse (fabric filter)	14	99 %
Cold side electrostatic precipitator (ESP)	76	73 %
Cold-side ESP/baghouse	2	73 %
Cyclone particulate removal	0	87 %
Unspecified type of electrostatic precipitator (electrofilter)	416	73 %
ESP/Baghouse	5	99 %
Hot side ESP	1	73 %
Multiclone particulate collector	4	50 %
Not applicable	608	0 %
None	6	0 %

Note: * Techniques and abatement efficiencies are described in TNO (2006). This report summarises LCP BREF, IPCC Guidelines and other information.

Source: Based on EPER, 2006 and Platts, 2006.

Table B.5 BAT AELs (mg/Nm³)

<table>
<tr><th>Pollutant</th><th>Type</th><th>Capacity</th><th colspan="5">Fuel</th></tr>
<tr><th></th><th></th><th></th><th>Hard coal</th><th>Brown coal</th><th>Fuel oil</th><th>Other oil</th><th>Gas*</th></tr>
<tr><td rowspan="6">CO</td><td rowspan="3">BREF, 'upper end of BAT' AEL</td><td>> 300</td><td colspan="2" rowspan="6">50</td><td rowspan="6">50</td><td rowspan="6">50</td><td rowspan="3">50</td></tr>
<tr><td>100–300</td></tr>
<tr><td>50–100</td></tr>
<tr><td rowspan="3">BREF, 'lower end of BAT' AEL</td><td>> 300</td><td rowspan="3">5</td></tr>
<tr><td>100–300</td></tr>
<tr><td>50–100</td></tr>
<tr><td rowspan="6">NMVOC (LCP BREF , p. 127)</td><td rowspan="3">BREF, 'upper end of BAT' AEL</td><td>> 300</td><td colspan="5" rowspan="6">5</td></tr>
<tr><td>100–300</td></tr>
<tr><td>50–100</td></tr>
<tr><td rowspan="3">BREF, 'lower end of BAT' AEL</td><td>> 300</td></tr>
<tr><td>100–300</td></tr>
<tr><td>50–100</td></tr>
<tr><td rowspan="6">NO_x</td><td rowspan="3">BREF, 'upper end of BAT' AEL</td><td>> 300</td><td>200</td><td>200</td><td>150</td><td>150</td><td>100</td></tr>
<tr><td>100–300</td><td>200</td><td>200</td><td>200</td><td>200</td><td>100</td></tr>
<tr><td>50–100</td><td>300</td><td>450</td><td>450</td><td>450</td><td>100</td></tr>
<tr><td rowspan="3">BREF, 'lower end of BAT' AEL</td><td>> 300</td><td colspan="2">50</td><td>50</td><td>50</td><td>20</td></tr>
<tr><td>100–300</td><td colspan="2">90</td><td>50</td><td>50</td><td>20</td></tr>
<tr><td>50–100</td><td>90</td><td>200</td><td>150</td><td>150</td><td>20</td></tr>
<tr><td rowspan="6">Dust (PM_{10})</td><td rowspan="3">BREF, 'upper end of BAT' AEL</td><td>> 300</td><td colspan="2">20</td><td>20</td><td>20</td><td>5</td></tr>
<tr><td>100–300</td><td colspan="2">25</td><td>25</td><td>25</td><td>5</td></tr>
<tr><td>50–100</td><td colspan="2">30</td><td>30</td><td>30</td><td>5</td></tr>
<tr><td rowspan="3">BREF, 'lower end of BAT' AEL</td><td>> 300</td><td colspan="2">5</td><td>5</td><td>5</td><td>5</td></tr>
<tr><td>100–300</td><td colspan="2">5</td><td>5</td><td>5</td><td>5</td></tr>
<tr><td>50–100</td><td colspan="2">5</td><td>5</td><td>5</td><td>5</td></tr>
<tr><td rowspan="6">SO_2</td><td rowspan="3">BREF, 'upper end of BAT' AEL</td><td>> 300</td><td colspan="2">200</td><td>200</td><td>200</td><td>10</td></tr>
<tr><td>100–300</td><td colspan="2">250</td><td>250</td><td>250</td><td>10</td></tr>
<tr><td>50–100</td><td colspan="2">400</td><td>350</td><td>350</td><td>10</td></tr>
<tr><td rowspan="3">BREF, 'lower end of BAT' AEL</td><td>> 300</td><td colspan="2">20</td><td>50</td><td>50</td><td>10</td></tr>
<tr><td>100–300</td><td colspan="2">100</td><td>100</td><td>100</td><td>10</td></tr>
<tr><td>50–100</td><td colspan="2">150</td><td>100</td><td>100</td><td>10</td></tr>
</table>

Note: * The emission levels of dust caused by using natural gas as a fuel are normally well below 5 mg/Nm³ and SO_2 emissions are well below 10 mg/Nm³ (15 % O_2) without any additional technical measures being applied (LCP BREF).

Source: LCP BREF (EC, 2006).

Table B.6 lists the values of the specific flue gas volumes as used in this study. The resulting LCP BREF consistent emission factors (g/GJ) are presented in Table B.7.

Table B.6 Fuel-specific flue gas volumes at the indicated excess air conditions

Fuel type	NCV* (MJ/kg)	Excess air (% O_2)	Specific flue gas volume** (m^3/G_J)
Hard coal	25.8	6	360
Brown coal	11.9	6	444
Fuel oil	40.4	3	279
Other oil	43.0	3	276
Gas	48.0	3	272

Note: *Net calorific values, from IPCC 2006 Guidelines.
**Specific flue gas volumes are calculated using the Rosin and Fehling (1929) relation; see Annex D.

Source: IPPC, 2006; Rosin and Fehling, 1929.

Table B.7 Fuel/capacity-dependent LCP BREF AEL consistent emission factors

Pollutant	Emission factor	Capacity (MW)	Emission factor (g/GJ)				
			Hard coal	Brown coal	Fuel oil	Other oil	Gas
NO_x	'Lower end of BAT' AEL	50–100	72	89	42	41	5
		100–300	32	40	14	14	5
		> 300	18	22	14	14	5
	'Upper end of BAT' AEL	50–100	108	200	126	124	27
		100–300	72	89	56	55	27
		> 300	54	89	42	41	27
SO_2	'Lower end of BAT' AEL	50–100	54	67	28	28	3
		100–300	36	44	28	28	3
		> 300	7	9	14	14	3
	'Upper end of BAT' AEL	50–100	144	178	98	97	3
		100–300	90	111	70	69	3
		> 300	72	89	56	55	3
CO	'Lower end of BAT' AEL	50–100	18	22	14	14	1.4
		100–300	18	22	14	14	1.4
		> 300	18	22	14	14	1.4
	'Upper end of BAT' AEL	50–100	18	22	14	14	14
		100–300	18	22	14	14	14
		> 300	18	22	14	14	14
NMVOC	'Lower end of BAT' AEL	50–100	1.8	2.2	1.4	1.4	1.4
		100–300	1.8	2.2	1.4	1.4	1.4
		> 300	1.8	2.2	1.4	1.4	1.4
	'Upper end of BAT' AEL	50–100	1.8	2.2	1.4	1.4	1.4
		100–300	1.8	2.2	1.4	1.4	1.4
		> 300	1.8	2.2	1.4	1.4	1.4
PM_{10}	'Lower end of BAT' AEL	50–100	1.8	2.2	1.4	1.4	1.4
		100–300	1.8	2.2	1.4	1.4	1.4
		> 300	1.8	2.2	1.4	1.4	1.4
	'Upper end of BAT' AEL	50–100	10.8	13.3	8.4	8.3	1.4
		100–300	9.0	11.1	7.0	6.9	1.4
		> 300	7.2	8.9	5.6	5.5	1.4

Source: LCP BREF (EC, 2006).

Table B.8 LCP Directive ELVs (mg/Nm^3)

Pollutant	Capacity (MW_{th})	Hard coal / Brown coal	Fuel oil / Other oil	Gas
NO_x	>500	500	400	200
	50–500	600	450	300
SO_2	> 500	400	400	35*
	100–500	2 000–400	(300 MW_{th}–500 MW_{th}) 1 700–400	
	50–100	2 000	(50–300 MW_{th}) 1 700	

Note: * Gaseous fuels in general.

Source: LCP Directive (EC, 2001a).

Table B.9 Fuel/capacity-dependent LCP Directive ELV consistent emission factors

Pollutant	Emission factor type	Capacity (MW)	Emission factor (g/GJ)				
			Hard coal	Brown coal	Fuel oil	Other oil	Gas
NO_x	LCP ELV consistent	> 500	180	222	112	110	54.4
		50–500	216	266	126	124	81.6
SO_2	LCP ELV consistent	> 500	144	177	112	110	9.5
		100–500	720–144	888–177	474–112	469–110	
		50–100	720	888	474	469	

Source: LCP Directive (EC, 2001a).

Annex C Gas-fired power plants in the study

Table C.1 Numbers of the reported types of the 511 identified gas-fired units (based on Platts WEPP Database) in the 450 EPER facilities of the EPER 2004 data set

Type	Type gas-fired LCP power plant	Abbreviation	Number	Average electrical capacity (MW_e)
Gas turbines	Combined-cycle	CC	2	394
	Combined-cycle single shaft configuration	CCSS	42	289
	Gas/Combustion turbine	GT	28	69
	Gas turbine in combined-cycle	GT/C	220	120
	Gas turbine with heat recovery	GT/H	2	11
	Gas turbine used for partial or complete steam-turbine re-powering	GT/R	25	215
	Gas turbine with steam send-out	GT/S	48	61
	Gas turbine in topping configuration with existing conventional boiler and T/G set	GT/T	41	70
Engines	Internal combustion (reciprocating engine or diesel engine)	IC	2	5
Boiler types	Steam turbine	ST	63	258
	Steam turbine in combined-cycle	ST/C	3	65
	Steam turbine with steam send-out	ST/S	35	100

Source: Based on EPER, 2006 and Platts, 2006.

Annex D Methodologies for the calculation of flue gas volumes for LCPs

Both BREF documents and the LCP Directive express emission levels — ELVs in the LCP Directive and AELs in the BREF documents — in terms of concentrations in the flue gas stream. To compare these with emissions, expressed in mass flows per unit of time, concentrations in the flue gases need to be multiplied by the flue gas volumes released within the same time span.

Three approaches are available to estimate the specific flue gas volumes from combustion of fuels.

Stoichiometry

The stoichiometric volume of flue gases due to the combustion of the carbon in 1 000 kg of hard coal and lignite are calculated in the table below. In ambient air, N_2 concentrations are approximately four times the O_2 concentrations.

In practice, operators will generally ensure that the amount of oxygen, needed for the combustion is not limited and conditions will be set such, that the flue gases contain a certain amount of excess oxygen. Following the requirements of the LCP Directive, a surplus of oxygen of 6 % for solid fuels (3 % for oil and gas) is used as reference. The theoretical flue gas volumes can now be calculated as presented below, using the so-called air factor

A similar calculation for fuel oil and natural gas result in theoretical flue gas volumes of 321.7 and 299.9 m^3/GJ respectively.

Empirical relation

In the real world, fuels may contain other components that can give rise to gaseous waste streams. In engineering practice the approach of

Table D.1 Calculation of stochiometric flue gas volumes for hard coal and lignite (Part 1)

	Hard coal	Lignite	Unit	Comment
[1] Mass of fuel	1 000	1 000	kg	
[2] net calorific value	25.8	11.9	MJ/kg	*IPCC 2006 Guidelines*
[3] Energy in fuel	25 800	11 900	MJ	[3] = [1] * [2]
[4] Carbon contents	0.0258	0.0276	kg/MJ	*IPCC 2006 Guidelines*
[5] Carbon in fuel	665.6	328.4	kg	[5] = [1] * [2]
	$C + O_2 + 4\ N_2 \rightarrow CO_2 + 4\ N_2$			
[6] Molar mass of C	12	12	g/mol	*Constant*
[7] Carbon in fuel	55 470	27 370	mol	[7] = [5]/[6] * 1 000
[8] CO_2 in flue gas	55 470	27 370	mol	[8] = [7]
[9] Flue gas = CO_2 + N_2	277 350	136 850	mol	[9] = (1 + 4) * [8]
[10] Molar volume	22.4	22.4	l/mol (273 K)	*Constant*
[11] Flue gas volume	6 212 640	3 065 440	l/1 000 kg	[11] = [9]* [10]
[12] Flue gas volume	6 213	3 065	m^3/1 000 kg	[12] = [11]/1 000
[13] Stochiometric flue gas volume	**240.8**	**257.6**	**m^3/GJ**	**[13] = [12]/([3] * 1 000)**

Table D.2 Calculation of stochiometric flue gas volumes for hard coal and lignite (Part 2)

[13] Stochiometric flue gas volume	240.8	257.6	m^3/GJ	[13] = [12]/([3] * 1 000)
[14] Surplus oxigen	6	6	%	Assumed
[15] Air factor	1.40	140	—	[15] = 21/(21–[14])
[16] Theoretical flue gas volume	337.1	360.6	m^3/GJ	[16] = [15] * [13]

Rosin and Fehling (1929) is frequently used. These authors developed an empirical relation between the net calorific value (NCV) and the flue gas volumes, taking the O_2 surplus into account. The empiric relation for the stoicheiometric flue gas volume (R) according to Rosin and Fehling (1929) is:

$$R = \frac{0.83}{1\ 000} \times NCV\ (\text{in kcal/kg}) + 1.65 = 0.198 \times NCV\ (\text{in MJ/kg}) + 1.65\ m^3/(\text{kg fuel})$$

The volume of air needed for this combustion is, according to these authors:

$$L = \frac{0.94}{1\ 000} \times NCV\ (\text{in kcal/kg}) + 0.50 = 0.225 \times NCV\ (\text{in MJ/kg}) + 0.50\ m^3/(\text{kg fuel})$$

To calculate the flue gas in surplus air the following formula holds:

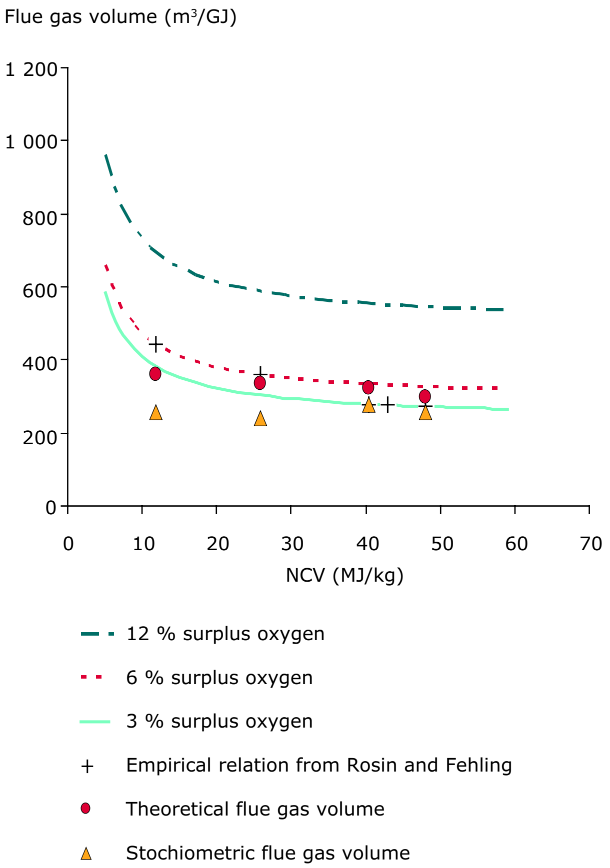
$$R_{total} = R + \left(\frac{21}{21-[O_2]} - 1\right) \times L\ m^3/(\text{kg fuel}) = (R + \left(\frac{21}{21-[O_2]} - 1\right) \times L/NCV\ m^3/MJ$$

The calculations in this report apply this empirical approach.

The graph below presents the results as a function of NCV for a range of fuels with 3, 6 and 12 % excess oxygen. The calculated stoichiometric and theoretical values are also indicated in Figure D.1.

From this analysis it is quite clear that the flue gas volumes are variable. Depending on the approach, the values might vary a few hundred m^3/GJ, especially for lignite. This might reflect the actual uncertainty in the assumed NCV values, especially for the low-quality solid fuels (lignite). Another important cause for the large variations might be the varying operational conditions in real- world boilers.

Figure D.1 Flue gas volumes in function of the net caloric value (NCV) using different calculation approaches



Annex E Comparison of methods to estimate thermal capacities of individual combustion units

The analyses in this report are based on the EPER 2004 data set in combination with the Platts WEPP Database on combustion plants.

In an initial analysis using the EPER 2001 data, the results were based on the linking of the EPER data set to activity data from a different database (SENCO) (SENCO, 2006). Since the capacity information in the SENCO database is rather incomplete, we derived the capacity class from the estimated fuel combusted based on the level of CO_2 emissions reported to EPER, and assuming a load of each combustion plant of 5 000 hours per year. This was assumed to be a realistic average estimate for coal-fired and probably also oil-fired LCPs, since most of these will be used in base load applications.

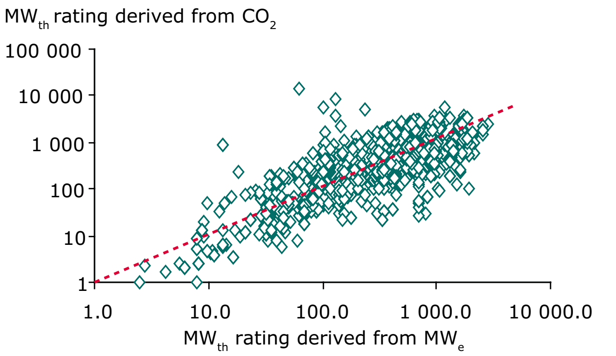
The current analysis in this report uses the MW_e rating for the individual units (from the Platts WEPP Database) using the efficiency factors shown in Table 2.2 to estimate the thermal capacity class of units. The graph below illustrates the relationship between the results of both approaches, using MW_e on unit level or estimating capacity from CO_2 emissions. The approach where the CO_2 emission is used is extended for this review to unit level and for the various fuel types different operation characteristics are estimated and used (see Table E.1).

The graph below shows that the correlation (fixed linear with zero intercept) between the MW_{th} rating resulting from the two estimates is high ($r^2 > 0.92$). The study therefore uses the MW_e approach to determine capacity classes for individual combustion units since this method uses more detail and is closer to the data provided on individual unit levels.

Table E.1 Assumed characteristic combustion plant operating times (in hours) in function of the fuel type

Assumed characteristic operation times		
Fuel	Usage	Operation time
Hard coal	90 %	7 884 hours
Brown coal	90 %	7 884 hours
Fuel oil	50 %	4 380 hours
Other oil	50 %	4 380 hours
Gas	20 %	1 752 hours

Figure E.1 Correlation (fixed linear with zero intercept) between the MW_{th} rating derived from MW_e and from CO_2 emissions



Source: Based on EPER, 2006 and Platts, 2006.

European Environment Agency

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