EUROPEAN COMMISSION

Integrated Pollution Prevention and Control

Reference Document on

Economics and Cross-Media Effects

July 2006

This document is one of a series of foreseen documents as below (at the time of writing, not all documents have been drafted):

Reference Document on Best Available Techniques . . .	**Code**
Large Combustion Plants	LCP
Mineral Oil and Gas Refineries	REF
Production of Iron and Steel	I&S
Ferrous Metals Processing Industry	FMP
Non Ferrous Metals Industries	NFM
Smitheries and Foundries Industry	SF
Surface Treatment of Metals and Plastics	STM
Cement and Lime Manufacturing Industries	CL
Glass Manufacturing Industry	GLS
Ceramic Manufacturing Industry	CER
Large Volume Organic Chemical Industry	LVOC
Manufacture of Organic Fine Chemicals	OFC
Production of Polymers	POL
Chlor – Alkali Manufacturing Industry	CAK
Large Volume Inorganic Chemicals - Ammonia, Acids and Fertilisers Industries	LVIC-AAF
Large Volume Inorganic Chemicals - Solid and Others industry	LVIC-S
Production of Speciality Inorganic Chemicals	SIC
Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector	CWW
Waste Treatments Industries	WT
Waste Incineration	WI
Management of Tailings and Waste-Rock in Mining Activities	MTWR
Pulp and Paper Industry	PP
Textiles Industry	TXT
Tanning of Hides and Skins	TAN
Slaughterhouses and Animals By-products Industries	SA
Food, Drink and Milk Industries	FDM
Intensive Rearing of Poultry and Pigs	ILF
Surface Treatment Using Organic Solvents	STS
Industrial Cooling Systems	CV
Emissions from Storage	ESB
Reference Document . . .	
General Principles of Monitoring	MON
Economics and Cross-Media Effects	*ECM*
Energy Efficiency Techniques	ENE

EXECUTIVE SUMMARY

This document is developed primarily to assist in the determination of best available techniques (BAT) under Directive 96/61/EC concerning integrated pollution prevention and control [20, European Commission, 1996]. The concept of BAT under IPPC takes into account the likely cost and benefits of measures as well as aiming to protect the environment taken as a whole to avoid creating a new and more serious environmental problem when solving another. BAT in a general sense is determined by stakeholder groups (technical working groups – TWGs) and is presented in a series of BAT reference documents (BREFs). BAT in BREFs serves as a reference point to assist in the determination of BAT-based permit conditions or for the establishment of general binding rules under Article 9 (8).

Article 9 (4) requires that permit conditions shall be based on BAT but taking into account the technical characteristics of the installation concerned, its geographical location and the local environmental conditions. Recital 18 furthermore leaves it for the Member State to determine how these local conditions can, where appropriate, be taken into consideration. Where there is a need to determine which option provides the higher level of protection to the environment in such local situations, the "cross-media" methodologies set out in this document may also help in this determination.

Some of the core principles of the Directive are discussed in this document insofar as they relate to taking account of the economic aspects of BAT and taking the environment as a whole (cross-media effects).

Chapter 1 - General information on economics and cross-media effects. This chapter discusses the terminology used in the Directive and explains the issues that are addressed in this document. Subsequent chapters set out a number of guidelines which may be used together or in combination to assist decision making relating to the determination of BAT. It is envisaged that the guidelines help to resolve differences in opinion as to BAT decisions by bringing structure to the discussion.

The purpose of the Directive is to achieve the integrated prevention and control of pollution arising from the industrial activities listed in Annex 1 of the Directive. The Directive lays down measures designed to prevent or, where that is not practicable, to reduce emissions to the air, water and land from these activities, including measures concerning waste, in order to achieve a high general level of protection of the environment taken as a whole. One of the principles of the Directive is that installations are operated in such a way that all appropriate preventive measures are taken against pollution, in particular through application of the Best Available Techniques (BAT).

The definition of BAT in the Directive and the principles that have to be taken into account are discussed.

Chapter 2 - Cross-Media guidelines. In order to determine BAT, there is a need to select the technique that is the most effective in achieving a high general level of protection of the environment taken as a whole. To achieve this in practice, there are likely to be instances where it will not be clear which technique offers the highest level of protection. Where this is the case, there may be a need to carry out an assessment to identify which technique is 'best'. Chapter 2 on cross-media effects sets out the methodologies that should help to determine this.

The chapter sets out four guidelines which can lead the user through the process of determining which out of a choice of techniques is the best environmental option.

Guideline 1 sets out the information that is necessary to scope and identify the alternative techniques under consideration.

Guideline 2 addresses the compilation of an inventory of the emissions from each of the alternative techniques and of the resources that they use. Such an inventory can be an important precursor to apply subsequent guidelines.

Guideline 3 sets out the steps necessary for estimating the environmental effects. There will usually be a range of emissions, discharges or resources used by the alternative techniques under consideration, and this guideline looks at ways of expressing the environmental effects so that comparisons can be made between the alternatives. Calculations are described that allow a wide range of pollutants to be expressed so that they can be compared and collated into 7 environmental themes; human toxicity, global warming, aquatic toxicity, acidification, eutrophication, ozone depletion and photochemical ozone creation potential. The guideline also considers the evaluation of energy use and the production of waste.

Guideline 4 describes the way in which the environmental themes that have been estimated in Guideline 3 can be interpreted. It details how different environmental effects can be compared and how the user can come to a decision as to which of the alternatives offers the highest general level of protection for the environment as a whole.

By following the guidelines in the cross-media chapter, the user should be in a better position to determine which option offers the highest level of protection for the environment. Carrying out the methodology also allows the user to set out the justification in a logical way so that the findings can be audited and validated at any point.

Chapter 3 - The costing methodology. The Directive also requires that the likely costs and benefits are taken into consideration when determining BAT. In order to determine the costs, a costing methodology is set out in Chapter 3. A further 5 guidelines are presented that allow the user to set out the costs transparently, so that the options can be validated, audited and compared in an equitable way.

Guideline 5 is analogous to guideline 1 in the cross-media methodology, in that it requires the user to scope and identify the alternative options.

Guideline 6 sets out the steps that are necessary for the user to gather and validate the cost data.

Guideline 7 requires the user to define which costs are being collated in the evaluation. This will require the identification of those costs that relate to investment expenditure and those that relate to operating and maintenance costs. In this guideline disaggregating the costs into as much detail as possible is preferred, so that they can be audited and validated more easily.

Guideline 8 sets out the steps that are necessary to process and present the cost information. Methodologies are described for dealing with exchange rates, inflation, discounting, and for calculating annual costs.

Guideline 9 discusses which costs should be attributed to environmental protection.

Chapter 4 - Evaluating the alternatives. Once the environmental effects have been established from Chapter 2, and the costs have been established from Chapter 3, there needs to be some way of comparing them. This chapter looks at ways of expressing cost effectiveness and at how the environmental benefits from implementing a technique can be valued. This can be useful as it allows the economic cost of implementing a technique to be balanced against the environmental benefit that it delivers. This can help clarify whether or not implementing a technique represents value for money in terms of environmental benefit.

Chapter 5 - Economic viability in the sector. In the Directive definition of BAT, “available” includes a requirement that techniques that are determined to be BAT are those that are *‘developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions’*. This chapter sets out a framework for assessing economic viability. Within this framework, the critical issues that need to be considered are the ‘Industry Structure’, the ‘Market Structure’, and the ‘Resilience’ of the sector.

Where it is found that implementing the proposed techniques will not undermine the viability of the sector but there still remain concerns about the economic impact, then an evaluation can be carried out as to whether the implementation can be eased by looking at the ‘Speed of Implementation’.

Although an assessment of economic viability is an inherent part of determining BAT, a detailed assessment is expected to be carried out only to resolve a claim that a technique (or a combination of techniques) is too expensive to be BAT. That claim is considered most likely to come from the industrial sector concerned and this chapter sets out a framework within which the arguments can be presented. The burden of proof in such an argument rests with those who object to the proposed BAT.

The Annexes - The annexes provide data and information that might be necessary when carrying out the methodologies described in this document.

- annexes 1 to 9 provide supporting information for the cross-media assessment
- annex 10 lists some useful sources for European price indices in support of the costing methodology
- annex 11 lists some financial ratios that might be useful in support of the economic viability valuation
- annex 12 lists external costs for some air pollutants in support of Chapter 4 on evaluating the alternatives
- annex 13 lists some of the methodologies that are used in support of the Directive in some Member States
- annex 14 describes the printing press example that was used in the development of the cross-media methodology
- annex 15 presents an example of NO_X reduction in municipal waste incinerator to illustrate application of the various methodologies in the document.

Although the methodologies that are described here have been simplified wherever possible, carrying out any of the assessments will still be an onerous process and should not be considered unless there is genuine disagreement about whether or not a proposed technique (or combination of techniques) is BAT.

The methodologies that are presented in this document assist a user to evaluate and set out both the environmental, and the economic consequences of introducing new techniques in support of the IPPC Directive. A key purpose of the methodologies described here is transparency, so that any part of the process can be validated or audited. Following the structure of the methodologies helps the user to achieve this transparency. The methodologies cannot make the decision, but can support subsequent expert judgement and provide a more consistent basis for the ultimate decision.

The EC is launching and supporting, through its RTD programmes, a series of projects dealing with clean technologies, emerging effluent treatment and recycling technologies and management strategies. Potentially these projects could provide a useful contribution to future BREF reviews. Readers are therefore invited to inform the EIPPCB of any research results which are relevant to the scope of this document (see also the preface of this document).

PREFACE

1. Status of this document

Unless otherwise stated, references to “the Directive” in this document means the Council Directive 96/61/EC on integrated pollution prevention and control. As the Directive applies without prejudice to Community provisions on health and safety at the workplace, so does this document.

This document forms part of a series presenting the results of an exchange of information between EU Member States and industries concerned on best available technique (BAT), associated monitoring, and developments in them. It is published by the European Commission pursuant to Article 16(2) of the Directive, and must therefore be taken into account in accordance with Annex IV of the Directive when determining “best available techniques”.

2. Relevant legal obligations of the IPPC Directive and the definition of BAT

In order to help the reader understand the legal context in which this document has been drafted, some of the most relevant provisions of the IPPC Directive, including the definition of the term “best available techniques”, are described in this preface. This description is inevitably incomplete and is given for information only. It has no legal value and does not in any way alter or prejudice the actual provisions of the Directive.

The purpose of the Directive is to achieve integrated prevention and control of pollution arising from the activities listed in its Annex I, leading to a high level of protection of the environment as a whole. The legal basis of the Directive relates to environmental protection. Its implementation should also take account of other Community objectives such as the competitiveness of the Community’s industry thereby contributing to sustainable development.

More specifically, it provides for a permitting system for certain categories of industrial installations requiring both operators and regulators to take an integrated, overall look at the polluting and consuming potential of the installation. The overall aim of such an integrated approach must be to improve the management and control of industrial processes so as to ensure a high level of protection for the environment as a whole. Central to this approach is the general principle given in Article 3 that operators should take all appropriate preventative measures against pollution, in particular through the application of best available techniques enabling them to improve their environmental performance.

The term “best available techniques” is defined in Article 2 (11) of the Directive as “the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole.” Article 2 (11) goes on to clarify further this definition as follows:

“techniques” includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;

“available” techniques are those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator;

“best” means most effective in achieving a high general level of protection of the environment as a whole.

Furthermore, Annex IV of the Directive contains a list of "considerations to be taken into account generally or in specific cases when determining best available techniques... bearing in mind the likely costs and benefits of a measure and the principles of precaution and prevention". These considerations include the information published by the Commission pursuant to Article 16 (2).

Competent authorities responsible for issuing permits are required to take account of the general principles set out in Article 3 when determining the conditions of the permit. These conditions must include emission limit values, supplemented or replaced where appropriate by equivalent parameters or technical measures. According to Article 9 (4) of the Directive, these emission limit values, equivalent parameters and technical measures must, without prejudice to compliance with environmental quality standards, be based on the best available techniques, without prescribing the use of any technique or specific technology, but taking into account the technical characteristics of the installation concerned, its geographical location and the local environmental conditions. In all circumstances, the conditions of the permit must include provisions on the minimisation of long-distance or transboundary pollution and must ensure a high level of protection for the environment as a whole.

Member States have the obligation, according to Article 11 of the Directive, to ensure that competent authorities follow or are informed of developments in best available techniques.

3. Objective of this Document

Article 16 (2) of the Directive requires the Commission to organise "an exchange of information between Member States and the industries concerned on best available techniques, associated monitoring and developments in them", and to publish the results of the exchange.

The purpose of the information exchange is given in recital 25 of the Directive, which states that "the development and exchange of information at Community level about best available techniques will help to redress the technological imbalances in the Community, will promote the worldwide dissemination of limit values and techniques used in the Community and will help the Member States in the efficient implementation of this Directive."

The Commission (Environment DG) established an information exchange forum (IEF) to assist the work under Article 16 (2) and a number of technical working groups have been established under the umbrella of the IEF. Both IEF and the technical working groups include representation from Member States and industry as required in Article 16 (2).

The aim of this series of documents is to reflect accurately the exchange of information which has taken place as required by Article 16 (2) and to provide reference information for the permitting authority to take into account when determining permit conditions. By providing relevant information concerning best available techniques, these documents should act as valuable tools to drive environmental performance.

4. Information Sources

This document represents a summary of information collected from a number of sources, including in particular the expertise of the groups established to assist the Commission in its work, and verified by the Commission services. All contributions are gratefully acknowledged.

5. How to understand and use this document

The information provided in this document is intended to be used as an input to the determination of BAT. When determining BAT and setting BAT-based permit conditions, account should always be taken of the overall goal to achieve a high level of protection for the environment as a whole.

The rest of this section describes the type of information that is provided in each section of the document.

Chapter 1 explains the issues that are addressed in this document and the links to the relevant articles of the Directive.

One objective of the Directive is to achieve a high level of protection of the environment taken as a whole. Where it is not obvious which alternative offers the higher level of protection, some way of comparing alternatives would be useful. Chapter 2 explains how a cross-media assessment could be carried out in order to determine which of the alternatives would achieve this higher level of protection. The Directive also requires that the likely costs and benefits of a technique be taken into consideration when determining BAT. To address this requirement, Chapter 3 describes the steps involved in gathering and manipulating cost data on alternative techniques in a transparent way.

Chapter 4 looks at ways of evaluating the alternatives and balancing the environmental improvements against the costs of implementing the techniques.

Within the definition of 'available' for BAT, there is a requirement that *"techniques shall mean those developed on a scale which allows implementation in the relevant industrial sector,* ***under economically and technically viable conditions****"*. Chapter 5 sets out the key issues to be considered when trying to determine if this condition is met.

Useful information and data to support the methodologies set out in this document are provided in the annexes along with 2 examples demonstrating the application of the methodologies.

Since the best available techniques change over time and better data or models may be available, this document will be reviewed and updated as appropriate. All comments and suggestions should be made to the European IPPC Bureau at the Institute for Prospective Technological Studies at the following address:

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Reference Document on
Economics and Cross-Media Effects

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SCOPE

This Reference Document on Economics and Cross-Media effects has been developed within the framework of the European IPPC BAT Information Exchange Forum. The methodologies set out in this document can provide assistance to both Technical Working Groups (TWGs) and permit writers when considering the environmental and economic conflicts that can occur when determining which techniques to implement under the IPPC Directive.

Technical Working Groups may need to resolve these conflicts when determining Best Available Techniques (BAT) in a BREF (Best Available Techniques Reference Document). Permit writers may also need to resolve some conflicts when determining IPPC permit conditions for an individual installation (which have to be based on BAT according to Article 9 (4) of the Directive). The methodologies described give a consistent structure to the decision making process and set out a clear and transparent framework for coming to a decision when balancing environmental impacts against the costs. Whilst the methodologies presented in this document are primarily developed for the determination of BAT at sector level (i.e. in BREFs), the approaches may have some use at local level although it should be noted that (a) the Directive makes no provision for any test of economic viability at any level other than the industry sector and (b) the Directive is explicit in recital 18 in that it is for Member States to determine how to take into account of the technical characteristics of an installation, its geographical location and any local environmental conditions.

This document addresses some of the core principles of the Directive:

1. General Information on Economics and Cross-Media Effects - Chapter 1 discusses the terminology used in the Directive. It also explains the issues that are addressed by this document. Although it is intended as an aid to the user, this description is inevitably incomplete and is given for information only. Any interpretation from it has no legal value and the statements made here do not in any way alter or prejudice the actual provisions of the Directive. There is some repetition of the wording of the preface in this chapter, but this is necessary to explain the full background to the development of this document.

2. Cross-Media Effects - A cross-media methodology is set out in Chapter 2 which allows the user to determine which alternative technique or techniques that might be implemented under IPPC offers the highest level of protection for the environment as a whole. The methodology sets out a transparent methodology for balancing the trade-offs that may have to be made in determining which is the best environmental option.

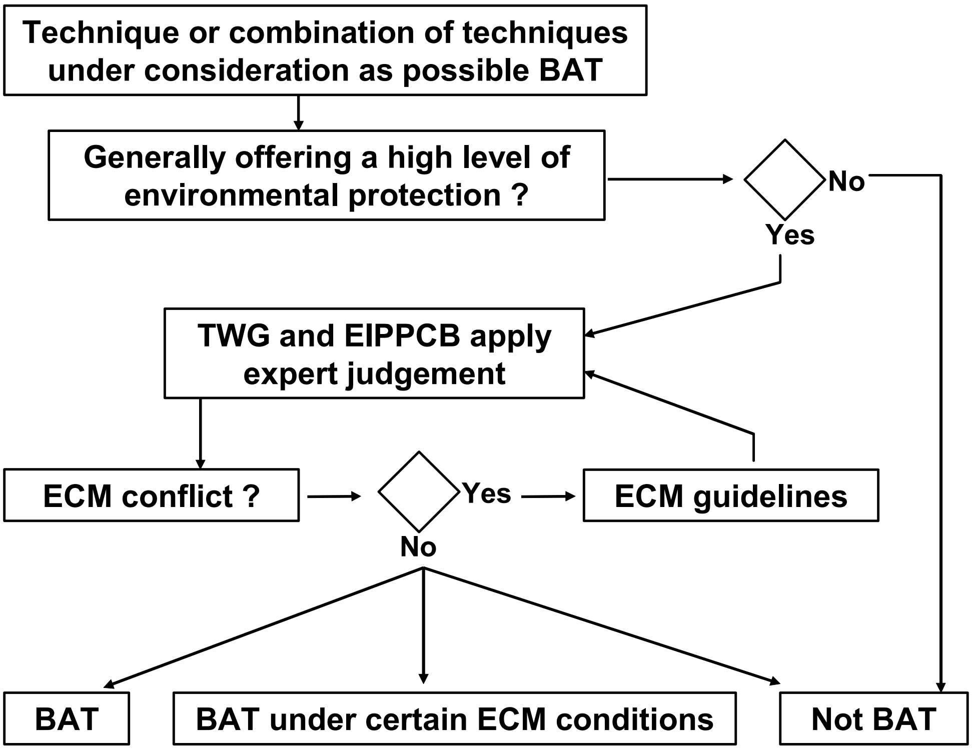
3. Costing Methodology - In many cases, the technique that offers the highest level of protection to the environment will be BAT, but the Directive also requires that the likely costs and benefits of implementing a technique are considered. Chapter 3 sets out a costing methodology, which will allow users and decision-makers to establish and present the costs of implementing a technique in a transparent way.

4. Evaluating the alternatives - Chapter 4 deals with some of the methods that can be used to balance economic costs against the environmental benefits. It uses the information gathered in the previous two chapters and allows comparison of alternative techniques that deliver different environmental benefits and which will have different costs.

5. Economic Viability - Chapter 5 discusses the requirement of the Directive to ensure that whichever technique is determined to be BAT does not undermine the economic viability of the industrial sector implementing that technique or those techniques. This chapter will only apply to the determination of BAT (not for an individual installation) and sets out a framework within which economic viability can be assessed.

The annexes provide data and information that might be useful when carrying out the assessments described in this document.

It is envisaged that these methodologies will only be applied in those cases where the best option is not obvious from the initial deliberations. **Where there is an obvious conclusion, or where there is broad agreement as to which alternative is the preferred option for implementation, then there will be no need to apply the methodologies set out here.**



The Role of the ECM guidelines in determining BAT at BREF sector level

1 GENERAL INFORMATION ON ECONOMICS AND CROSS-MEDIA EFFECTS

This chapter explains the background of this reference document on 'Economics and Cross-Media' effects and explains the links with the relevant articles of the Directive. Text from the directive is presented in italics in the boxes below.

The purpose and scope of the IPPC Directive is set out in Article 1.

> ***Article 1***
> ***Purpose and scope***
>
> *The purpose of this Directive is to achieve integrated prevention and control of pollution arising from the activities listed in Annex I. It lays down measures designed* ***to prevent or, where that is not practicable, to reduce emissions in the air, water and land from the above-mentioned activities, including measures concerning waste, in order to achieve a high level of protection of the environment taken as a whole****, without prejudice to Directive 85/337/EEC (27 June 1985 on the assessment of the effects of certain public and private projects on the environment) and other relevant Community provisions.*

To help achieve this objective, industrial processes that fall within the scope of Annex I of the Directive require a permit based on 'Best Available Techniques' (BAT).

The definition of BAT is given in Article 2.

> ***Article 2***
> ***Definitions***
> *For the purposes of this Directive:*
>
> ***'best available technique'*** *shall mean the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole:*
>
> - ***'techniques'*** *shall include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned,*
>
> - ***'available'*** *techniques shall mean those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator,*
>
> - ***'best'*** *shall mean most effective in achieving a high general level of protection of the environment as a whole.*
>
> *In determining the best available techniques, special consideration should be given to the items listed in Annex IV;*

The items listed in Annex IV of the Directive are set out on the next page.

ANNEX IV

Considerations to be taken into account generally or in specific cases when determining best available techniques, as defined in Article 2 (11), bearing in mind the likely costs and benefits of a measure and the principles of precaution and prevention:

1. *the use of low-waste technology;*
2. *the use of less hazardous substances;*
3. *the furthering of recovery and recycling of substances generated and used in the process and of waste, where appropriate;*
4. *comparable processes, facilities or methods of operation which have been tried with success on an industrial scale;*
5. *technological advances and changes in scientific knowledge and understanding;*
6. *the nature, effects and volume of the emissions concerned;*
7. *the commissioning dates for new or existing installations;*
8. *the length of time needed to introduce the best available technique;*
9. *the consumption and nature of raw materials (including water) used in the process and their energy efficiency;*
10. *the need to prevent or reduce to a minimum the overall impact of the emissions on the environment and the risks to it;*
11. *the need to prevent accidents and to minimise the consequences for the environment;*
12. *the information published by the Commission pursuant to Article 16 (2) or by international organisations.*

Within the exchange of information organised under Article 16 of the Directive, BAT is determined in a general sense with input primarily from European stakeholders. The results of the information exchange are incorporated in the series of Best available techniques REFerence (BREF) documents. Each BREF is developed with a technical working group (TWG). The conclusions on BAT in a general sense within BREFs serve as a reference point to assist in the determination of BAT-based permit conditions or for the establishment of general binding rules under Article 9 (8).

In the determination of BAT there may be a need to decide which technique offers the better environmental performance in the context of the industrial process. In this respect, trade-offs can arise, where choices have to be made between disposing of a pollutant to different environmental media or between different releases to the same environmental medium. For example, using water to scrub an air emission transfers that pollutant from the air to water and will consume water and energy in the scrubbing process. This energy consumption leads, in an indirect way, to additional air emissions within the same medium (air). Chapter 2 of this document sets out a 'Cross-Media' methodology to help resolve these trade-offs and to determine which alternative offers the highest level of protection for the environment as a whole.

Article 9 (4) requires that permit conditions shall be based on BAT but taking into account the technical characteristics of the installation concerned, its geographical location and the local environmental conditions. Recital 18 furthermore, leaves it for the Member State to determine how these local conditions can, where appropriate, be taken into consideration. Where there is a need to determine which option provides the higher level of protection to the environment in such local situations, the 'cross-media' methodologies set out here may also help in this determination. The elements of the methodologies that might be useful in the local situation are discussed in more detail in the text.

Article 10 of the Directive provides that conditions stricter than BAT may be required to ensure compliance with an environmental quality standard.

Article 10

Best available techniques and environmental quality standards

Where an environmental quality standard requires stricter conditions than those achievable by the use of the best available techniques, additional measures shall in particular be required in the permit, without prejudice to other measures which might be taken to comply with environmental quality standards.

Some screening tools that might be used to determine which emissions might need to be assessed in more detail in the local situation are described in Section 2.6.4. If screening identifies a pollutant to be a concern, there may be a need to model the impacts in more detail and to take into account specific local concerns such as prevailing weather conditions, dilution, topography and interaction with other local sources of pollution. Even with these screening tools, consultation with the local permitting authority is likely to be necessary, as there may be specific local concerns that are not considered here.

The definition of 'available' in BAT requires that the costs and advantages of implementing a technique are taken into consideration. Chapter 3 sets out a costing methodology so that the costs of the alternative options under consideration can be compared equitably. It is important that these costs are reported and handled transparently so that there are no distortions introduced into the assessment. The Directive refers to benefits and to advantages. Within this document the term "benefits" is used to refer to benefits or advantages as mentioned in the Directive.

Once the environmental effects and the cost of implementation have been established, a method of balancing these two issues is needed. Chapter 4 discusses methodologies that could be used to balance the environmental effects of a technique against the cost of implementation.

Also within the definition of *'available'* in BAT there is a requirement that the technique is able to be implemented *"under economically and technically viable conditions"*. Chapter 5 discusses the critical factors in determining the economic viability of a technique, which helps to structure the debate on economic viability that might be required in the determination of BAT. This chapter is only applicable in the determination of BAT; the Directive makes no provision for a test of economic viability in the local situation.

The Annexes provide data for carrying out the various assessments and other reference material that may be needed in the evaluation.

All the methodologies described in this document have been developed as practical tools to assist the decision-making process which will inevitably involve expert judgement. Nevertheless, it does take time, resources and expertise to carry out the assessments and there will often be a need to apply some pragmatism when making the decision. It is anticipated that these methodologies will only be used in cases where there is no clear preference, or when there is some contention about which technique is the optimum choice. If, at any stage, there is general agreement that a technique, or combination of techniques, is BAT without the need for further assessment, there is no need to apply all the methodologies set out here to prove it, simply set out the justification for the decision. This test is true throughout this document, whether it be for the cross-media assessment, the costing methodology, or for determining economic viability in the sector.

The methodologies described in this document are shown schematically below. The logical sequence to follow if applying all of the methodologies would be: 1) the cross-media methodologies are described as guidelines in Figure 1.1, 2) the costing methodology Figure 1.2, 3) the evaluation of the alternatives Figure 1.3, and finally 4) discussion of economic viability in the sector Figure 1.4. As mentioned earlier, if at any point the answer becomes obvious, then there will be no need to apply the methodologies set out here, the user should simply set out the justification and make the determination. There may be cases where the user will only need to establish one or other aspect of the determination. For example, if the environmental benefit of a technique is well known, the costing methodology could be used separately to determine the costs without resorting to the full cross-media methodology. To make these methodologies as adaptable as possible, they have been developed modularly and can be used independently.

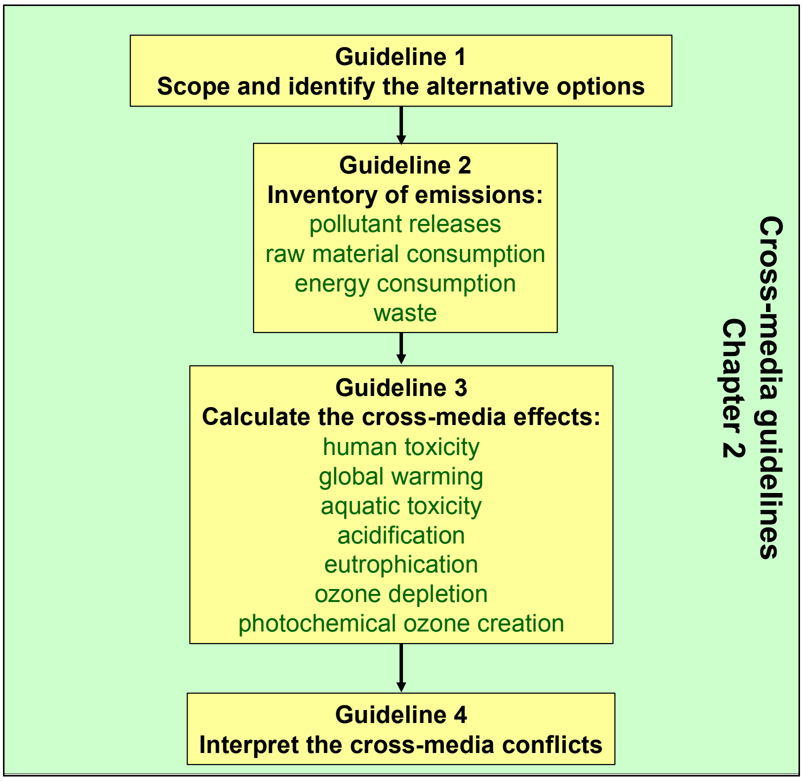


Figure 1.1: The cross-media guidelines

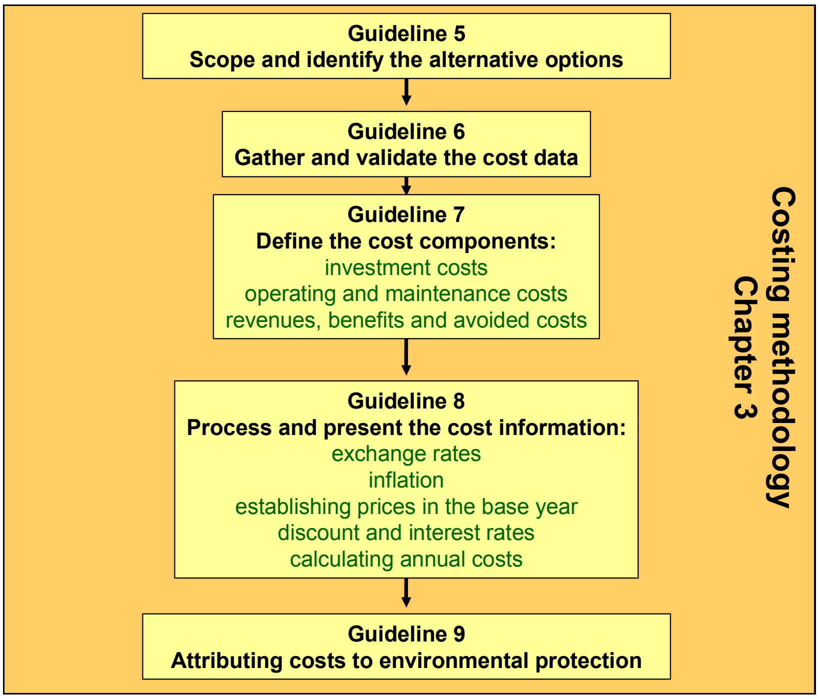


Figure 1.2: Costing methodology

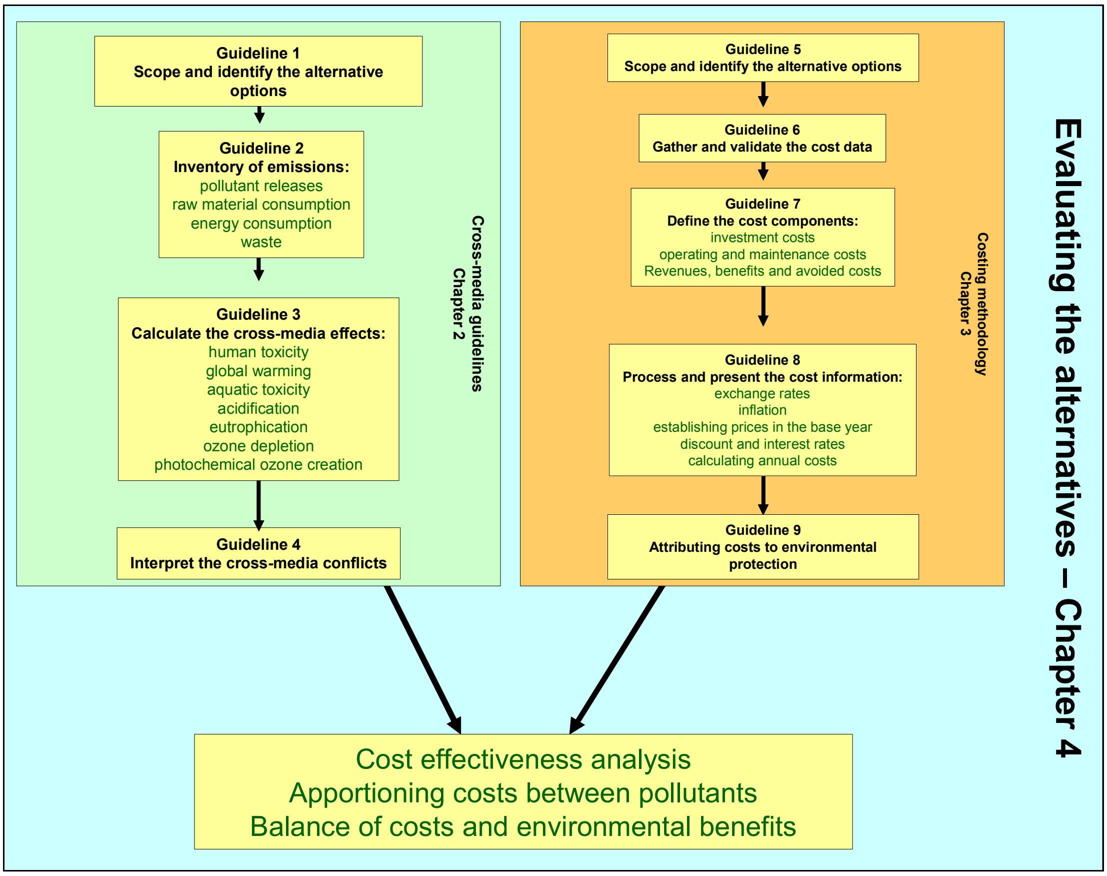


Figure 1.3: Evaluating the alternatives

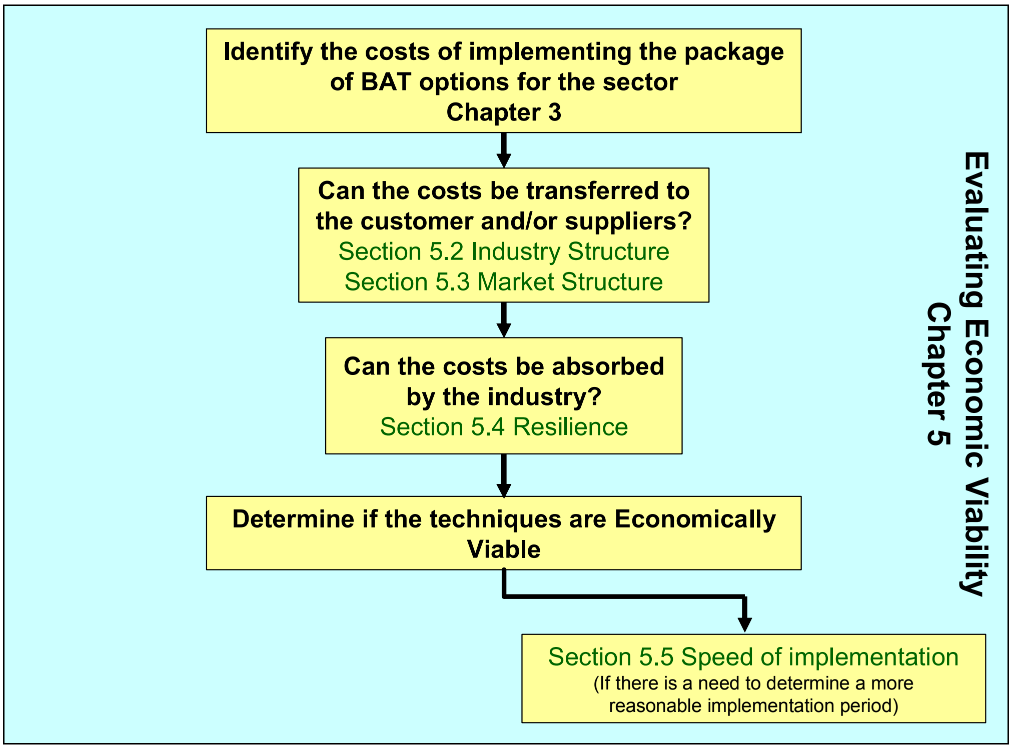


Figure 1.4: Economic viability in the sector

2 CROSS-MEDIA GUIDELINES

2.1 Introduction

The operation of any IPPC process by its very nature will have environmental effects. To comply with the requirements of the Directive these environmental effects need to be prevented, or where this is not possible they should be minimised to ensure that a high level of protection is given to the environment as a whole. When there are alternative techniques that could be implemented for the IPPC process and there is a choice as to where the resulting pollution is disposed to, the least environmentally damaging option should be chosen. Determining which option is the least environmentally damaging is not always a simple process and there may be trade-offs that have to be made in coming to the decision as to which technique is the best option.

The term 'Cross-Media effects' is used in this document to describe the environmental effects of the options under consideration. Choosing between alternative options might require a choice to be made between releasing different pollutants in the same environmental medium (e.g. different technology options might release different air pollutants). In other cases, the choice might be between releasing to different media (e.g. using water to scrub an air emission thereby producing waste water or filtering a water discharge to produce a solid waste).

When determining BAT, most of the cross-media conflicts that are encountered should be relatively simple to understand and it will be easy to come to a decision. In other cases, the trade-offs will be more complex. The purpose of the cross-media methodology set out below is to provide guidance on how to choose which option is best for the environment in these more complex cases. When the methodology is applied it should help to clarify the decision making process and ensure that any conclusions are determined in a consistent and transparent way.

The methodology is based on work carried out by the IPPC Technical Working Group on economics and cross-media effects and reported in the document 'Cross-Media Methodology for BAT Purposes' [26, Breedveld, et al., 2002]. The methodology as described here is a truncated version of Life Cycle Analysis, which has been adapted so that the assessment is restricted to the boundaries of the IPPC process. Note that the terms used in this document do not fully conform to the terminology used in the ISO standards 14040 series for LCA.

To evaluate the cross-media effects, techniques are described which allow an inventory to be drawn up of the emissions from the process. Once the inventory has been developed, the data can be compiled to establish the environmental effects from the alternative techniques under consideration. These environmental effects can then be compared, to determine the least environmentally damaging option.

The terms **'emissions'** and **'consumptions'** are used throughout this document, to cover all of the environmental effects, which include emissions (releases such as air emissions, water discharges, waste, etc.) and resources consumed by the process, such as energy, water and raw materials.

The approach described here might also be used in determining permit conditions for an individual installation, however the methods used and the level of detail required can be significantly different. The cross-media methodology will not address local environmental effects, but some screening tools, to help identify the pollutants that are likely to cause the greatest concern in the local situation, are discussed in Section 2.6.4. In many cases, there may be a need to carry out detailed modelling of the fate and effects of the individual pollutants identified by using this screening tool.

Figure 2.1 shows the steps involved in the cross-media methodology.

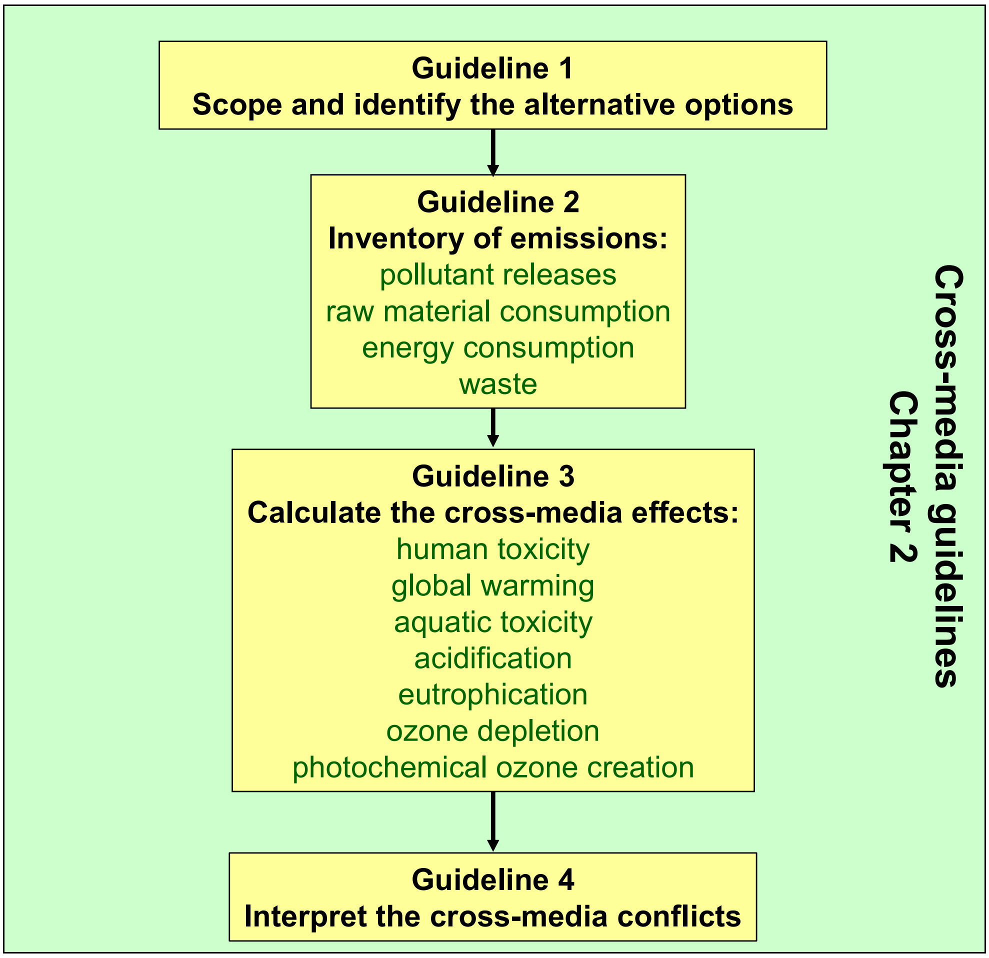


Figure 2.1: Flow chart for the cross-media guidelines
Note – If, at any point, there is sufficient information to come to a conclusion, then the user should stop at that point and set out the justification for the decision

The cross-media methodology consists of four steps:

1. Guideline 1 - Scope and identify the alternative options: the initial step in the process is to scope and identify the alternative options that are available and that could be implemented. The boundaries of the assessment need to be set at this stage, with the normal expectation being that the assessment will be restricted to the boundary of the IPPC process.

   If at this stage there is sufficient justification to come to a conclusion, the user should stop and set out the justification for the decision.

2. Guideline 2 - Inventory of emissions: this step requires the user to establish an inventory of emissions for each of the alternative options under consideration.

   If at this stage there is sufficient justification to come to a conclusion, the user should stop and set out the justification for the decision.

3. Guideline 3 - Calculate the cross-media effects: this step allows the user to express the potential environmental effects anticipated from each of the pollutants within seven environmental themes (e.g. human toxicity, global warming, aquatic toxicity, etc.). This is so that a wide range of pollutants can either be compared directly or aggregated and expressed as a total effect.

Two approaches are described which allow the mass emissions of an individual pollutant to be expressed as an equivalent effect (e.g. the Global Warming Potential of a wide range of greenhouse gases can be expressed as kg of CO_2 equivalents). These allow individual pollutants to be summed and expressed as a total potential effect within each of the seven environmental themes. The user may then be able to compare the alternatives to estimate which option has the lowest potential effect in each theme.

If at this stage there is sufficient justification to come to a conclusion, the user should stop and set out the justification for the decision.

4. **Guideline 4 - Interpret the cross-media effects:** this final step in the cross-media guidelines discusses how the user can interpret which of the alternative options offers the highest level of protection for the environment. Different approaches for comparing the result of the cross-media assessment are discussed.

The degree of uncertainty in the basic data collected for Guidelines 1 and 2 is relatively low compared to the uncertainty after subsequent manipulation when guidelines 3 and 4 are applied.

When developing an IPPC proposal, there may be a parallel requirement to carry out an Environmental Impact Assessment in order to comply with the requirements of Directive 85/337/EC on the assessment of the effects of certain public and private projects on the environment (EIA Directive) [19, European Commission, 1985]. Some of the procedures set out in the cross-media methodology described in this document require similar basic information that may need to be gathered to meet the requirements of the EIA Directive. Some of this basic information could thus support both purposes (The information that has to be supplied for Annex III of the EIA Directive is listed in Annex 9 of this document).

2.2 Simplification techniques

The cross-media methodology should be sufficient to come to a decision in most cases, however, it is impossible to be prescriptive when deriving the solution to what can be a very complex judgement. To ensure that this methodology is as practical and as usable as possible, it has been necessary to simplify some of the steps that need to be followed when applying it. Users need to be aware of these simplifications and realise that, in some circumstances, there will also be a need to consider wider issues than just those that are included here. Because of these limitations, users will need to accept that there will occasionally be a need for more weight to be given to expert judgement in the assessment process. However, whether applying the full methodology, parts of it, or when using expert judgement, the final decision always needs to be justified to maintain transparency of the decision making process.

The simplification techniques used in the Cross-Media methodology are:

Simplification Techniques

- **Define system boundaries** – The boundaries set for the assessment should be limited to the boundaries set for an installation in the IPPC Directive. An installation is defined in the Directive as:

  "…….. *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.*"

  There is no intention for this methodology to be extended beyond the installation boundary, but there will be occasions where upstream and downstream processes can have a significant effect on the environmental performance of the proposal. For these occasions it may be appropriate to extend the assessment, but this is only likely to happen in exceptional circumstances. If the assessment is extended, the decision to do so will have to be justified in each individual case. Energy and waste, for example, can be addressed within the installation boundary but only in a generic fashion. For a specific case, it may be decided to assess impacts of energy consumption and/or waste treatment or disposal in more detail.

- **Accept obvious conclusions** – If at any point when applying the methodology the decision becomes clear, then the process can be stopped at that point, with no need to proceed any further. The user will then need to set out the justification for the decision taken at this stage.

- **Exclude common factors from the Cross-Media assessment** - When scoping and identifying the options, there may be an opportunity to exclude common factors (for example, it may be possible to exclude energy use, some emissions or raw material consumption if the alternatives have the same values in these respects). It is important to remember that any issues excluded from the cross-media assessment might well be important later in the assessment process (for example, when applying the costing methodology) and so, for transparency, any common factors that are excluded should be stated clearly when scoping and identifying the options.

- **Exclude insignificant effects** – Although there is a value judgement here and exclusion should be undertaken with care, effects that do not have a significant effect on the outcome can be excluded. However those issues that are excluded because they are considered insignificant will still need to be declared and justified to maintain transparency when presenting the results.

- **Standard sources of data** – Once the inventory data are known, equivalence factors can be used to quantify the cross-media effects. Common inventory data are provided in the annexes of this document and can be used for calculating the environmental effects of the alternative options (for example, see Annex 2 – Global Warming Potentials). These databases are derived from established sources and are thought to be sufficiently accurate for comparing the environmental effects between the alternative techniques that are under consideration.

- **Calculating the effects** – Calculations should be carried out as transparently as possible to best inform expert judgement in comparing alternatives.

2.3 Guideline 1 – Scope and identify the alternative options

The first stage in the cross-media methodology is the definition of the alternative proposals to be considered. It is important that the alternatives are described in sufficient detail to prevent any ambiguity or misunderstanding, either in the scope of the technique or the boundaries of the assessment. Normally the boundaries selected will be those of a typical installation (see Directive definition on page 10) but if effects outside the boundary of a typical installation are included, this should be clearly stated with an explanation as to why.

In some cases, the aim of using the cross-media methodology is to appraise different techniques or combinations of techniques that deal with control of a specific pollutant, e.g. ‘nitrogen oxides’, ‘particulate emissions’ or ‘biological oxygen demand’. In other cases, where choices exist in the basic technology or process routes, it may be more appropriate to include the whole installation within the scope, including the pollution techniques installed, so that the overall environmental benefits of each option can be compared.

Bearing in mind the considerations listed in Annex IV of the Directive, priority should be given to the selection of techniques that prevent or reduce emissions or to cleaner technologies, as these will tend to result in the lowest environmental impact. The alternative measures that might be assessed include:

- **process design,** e.g. cleaner technology; changes or replacements to processes, or plants, or equipment; alternative synthesis routes; etc.
- **selection of raw materials,** e.g. cleaner fuels, less contaminated raw materials, etc.
- **process control,** e.g. process optimisation, etc.
- **housekeeping-type measures,** e.g. cleaning regimes, improved maintenance, etc.
- **non-technical measures,** e.g. organisational changes, staff training, the introduction of environmental management systems, etc.
- **end-of-pipe technology,** e.g. incinerators, waste water treatment plants, adsorption, filter beds, membrane technology, noise protection walls, etc.

When determining the scope of the assessment and identifying the alternative options, the size or capacity of the proposal will need to be fixed to ensure that the alternatives are compared on an equal basis. Ideally this will be based on alternatives that correspond to the same capacity in terms of finished product (e.g. ‘The alternative options for a hot rolling mill with a capacity of 25 tonnes of steel per hour were assessed’). There will, of course, be occasions when the alternatives cannot be fixed at the same size, for example if the technology is bought ‘off-the-shelf’ and therefore determined by the size of the unit supplied by the equipment suppliers. If this is the case, then any differences between the alternatives need to be clearly stated to avoid distorting the results.

The simplification techniques described earlier should also be applied at this stage and, to ensure transparency, any exclusions of common factors or insignificant effects should be stated. It should be borne in mind, however, that these issues may still be important when assessing the total environmental impact of the technique, or when applying the costing methodology.

It is possible that at this stage, the cross-media conflicts and the different environmental effects may be obvious enough to allow a decision to be made. At this point, the user should then consider whether there is any need to proceed further with the cross-media methodology, or if there is sufficient justification to support a conclusion at this point. If a conclusion can be reached, then the reasons for that conclusion will still need to be justified and reported, to ensure that the decision making process remains transparent. However, if there is still doubt as to which alternative provides the greatest level of protection for the environment, then the user will need to proceed to the next stage, i.e. to Guideline 2.

2.4 Guideline 2 – Inventory of consumptions and emissions

The significant environmental releases and the resources consumed by each of the alternative techniques under consideration need to be listed and quantified. This list should cover the pollutants released, the raw materials consumed (including water), the energy used and the wastes produced.

Some useful sources of information that might provide data on releases and resources consumed include:

- monitoring information from existing installations of a similar type or configuration
- research reports
- data from pilot plant studies
- calculated data, such as mass balance information, stoichiometric calculations, theoretical efficiencies, or scaled-up laboratory data
- information from the information exchange process (Article 16 of the Directive)
- information from equipment vendors or manufacturers.

The data should be as complete as possible, so that all the emissions, raw material inputs, energy used and waste produced are accounted for. Both point source and fugitive emissions need to be assessed. For transparency, the details of how the data were derived or calculated should also be provided. Recording the source of data is also important, so that it can be validated and verified where necessary.

Ideally, the mass of emissions released and the mass of resources consumed should be used (for example, kg emitted/year or kg emitted/kg of product). Information might also be available as a release rate (for example, reported as mg/m^3 or mg/l), which might be particularly important for batch techniques or for techniques that follow a cycle where concentrations may be particularly high at certain stages in the process.

2.4.1 Data quality

Data quality is a critical issue in this assessment, so the user should question and evaluate the quality of the data available, and to compare data from different sources where necessary. In many cases, there will be quantitative measures available regarding the uncertainty that can be attributed to the data, e.g. based on the accuracy of the analysis techniques that were employed (for example emissions monitoring results might be reported as $100\ mg/m^3 \pm 25\ \%$). Where this information is available it should be recorded, so that it can be used to determine the upper and lower ranges for the sensitivity analysis, which may be necessary later in the assessment.

Where quantitative measures are not available, a data quality rating system can be used to give a qualitative indication of the data reliability. The rating score gives a rough guide to the confidence in the data and may also help to indicate how thorough the sensitivity analysis will need to be.

The data quality rating system described below can give a simple indication of the quality of the data and whether it is valid to use the data in an assessment. This system was originally developed for the EMEP/CORINAIR Emission Inventory Guidebook [5, EMEP CORINAIR, 1998].

Data quality rating system

A. An estimate based on a large amount of information fully representative of the situation and for which all background assumptions are known.

B. An estimate based on a significant amount of information representative of most situations and for which most of the background assumptions are known.

C. An estimate based on a limited amount of information representative of some situations and for which background assumptions are limited.

D. An estimate based on an engineering calculation derived from a very limited amount of information representative of only one or two situations and for which few of the background assumptions are known.

E. An estimate based on an engineering judgement derived only from assumptions.

It is important that data of ‘inferior’ quality are not suppressed nor excluded from the assessment by requiring only data of ‘A’ or ‘B’ quality. Otherwise, if less reliable data are excluded, then applying the methodology might become a barrier to innovation rather than a tool to improving environmental performance, as innovative techniques, by their very nature, will not have as much data available as established techniques. If only data of inferior quality are available, then conclusions should be drawn cautiously. However, conclusions can still be drawn and can form the basis for further discussion or to identify where more reliable data needs to be obtained.

2.4.2 Energy (Electricity and Heat)

Energy is a continuous input to most industrial processes. Some may be supplied from ‘primary energy sources’ such as coal, oil and gas, whereas others may be from ‘secondary energy sources’ that were generated outside the IPPC boundary of the process and then supplied in the form of electricity and heat. Primary energy sources are already considered in the cross-media assessment in the form of raw materials used and the emissions from the process, and so are not considered in any more detail here. This section outlines a method of taking into consideration the environmental impact of the secondary energy sources used in the process.

2.4.2.1 Energy efficiency

Before considering how the environmental impact of 'secondary energy sources' can be assessed, it is worth mentioning the requirements of the Directive to minimise the production of waste and for energy to be used efficiently. Article 3 of the Directive states that:

Article 3
General principles governing the basic obligations of the operator

Member States shall take the necessary measures to provide that the competent authorities ensure that installations are operated in such a way that:

(a) all the appropriate preventive measures are taken against pollution, in particular through application of the best available techniques;

(b) no significant pollution is caused;

(c) waste production is avoided in accordance with Council Directive 75/442/EEC of 15 July 1975 on waste(11); where waste is produced, it is recovered or, where that is technically and economically impossible, it is disposed of while avoiding or reducing any impact on the environment;

(d) energy is used efficiently;

(e) the necessary measures are taken to prevent accidents and limit their consequences;

(f) the necessary measures are taken upon definitive cessation of activities to avoid any pollution risk and return the site of operation to a satisfactory state.

For the purposes of compliance with this Article, it shall be sufficient if Member States ensure that the competent authorities take account of the general principles set out in this Article when they determine the conditions of the permit.

This obligation remains on the operator. Every effort should thus be made to ensure that the energy used within the plant is used efficiently. The methodology set out below does not undermine or contradict this requirement to use energy efficiently, but rather, establishes the environmental effects of that energy so that the alternatives can be compared.

2.4.2.2 Electricity and heat used in the process

Electricity and heat can form a significant part of the total environmental impact of the IPPC process. In most cases, the source of electricity or heat used will be the same whichever alternative technique is selected. In these cases, it will be sufficient to compare the electricity and heat requirements of the alternatives that are under consideration directly, preferably both expressed in GJ and no further analysis will be needed.

2.4.2.3 The European electricity and heat mix

In other cases there might be trade-offs that have to be made between the environmental impacts of the secondary energy sources used in the process and other pollutants that might be released. The environmental impact from this energy, regardless of whether it is in the form of electricity or heat will depend on the power plant technology and on the fuel source that is used to generate it. For example, when assessing an end-of-pipe abatement plant that is powered by electricity, the environmental impact of the additional electricity used has to be traded-off against whichever pollutant is being abated. If the abatement plant has a significant electricity demand and the abated pollutant is relatively benign, then depending on the environmental consequences of the electricity generation, abating the pollutant may provide less overall protection to the environment as a whole. However, few cases are known where the impact of electricity use outweighs the benefits of abating the pollutant in question.

The 'European electricity and heat mix' is a simplified approach for deriving emission factors to account for the environmental effects of the electricity and heat used. Multiplication factors have been derived for emissions of SO_2, CO_2, and NO_2, and for the consumptions of oil, gas and coal per GJ of electricity and heat consumed. These multiplication factors have been derived from energy sources averaged across Europe (see Annex 8).

For example, a process that uses 10 GJ of electricity per year will have the following impact, as calculated from the multiplication factors presented in Annex 8:

Resources used		**Emissions**	
Oil (kg)	90.1		
Gas (m^3)	69.2		
Coal (kg)	157		
Brown Coal (kg)	346.4		
		SO_2 (kg)	1
		CO_2 (kg)	1167.1
		NO_2 (kg)	1.6

Table 2.1: Resources used and emissions caused by a process that uses 10 GJ of electricity per year

The multiplication factors presented in Annex 8 are, of course, generalisations and in cases where the environmental impact of the electricity and heat used is critical to the decision, it may be appropriate to carry out a sensitivity analysis or to derive more specific data for the calculation. The European energy mix is not so appropriate for use at anything other than at European level.

Users should be cautious about attempting to derive more specific information as this may entail gathering large amounts of data on the source of the electricity or heat and the technology and fuel used to generate it. The electricity and heat used varies between individual member states and also between individual sites. It may also change as the prices of various energy sources fluctuate. If the energy used is in the form of electricity from a grid, then there are further complications, as the power sources usually vary depending on the time of day. Collating more detailed information is only likely to be necessary in cases where the electricity and heat used by the process is critical for making the decision.

Proposed amendments to Directives 96/92/EC and 98/30/EC concerning common rules for the internal market in electricity and natural gas may require suppliers make information on the environmental impacts of their activities available to their customers and this could, therefore, provide useful information for evaluating the environmental effects of the energy used in the industrial process.

Whether the multiplication factors from the European electricity and heat mix, or more specific information is used, it is essential that the source of the data used and the way in which the data are manipulated remains transparent. Care needs to be taken to ensure that any assumptions made about the electricity and heat used by the process are clear. Any possible distortions that may be caused by these assumptions need to be clearly understood, both by users and decision-makers.

2.4.3 Waste

Industrial processes generate solid and liquid waste, which may be treated or disposed of on-site, or removed from the plant for treatment or disposal elsewhere. The Directive seeks to avoid the production of waste wherever possible by encouraging the selection of techniques that use low-waste technology and techniques that allow for the recovery and recycling of any wastes that arise. Where it is technically or economically impossible to avoid the production of waste, then it should be disposed of in such a way that avoids or minimises any impact on the environment.

When comparing alternative techniques that generate wastes, an analysis of the quantity, composition and likely environmental effects of the waste produced can be useful. As a pragmatic approach to assessing which alternative offers the highest level of protection for the environment as a whole, the simple methodology described below should normally be sufficient.

Simple methodology. When deriving the inventory, the wastes generated by each of the alternative techniques under consideration can be split into three categories, i.e:

1) **inert waste**
2) **non-hazardous waste**
3) **hazardous waste.**

These categories should be expressed in kg of waste produced.

For these three categories of waste, the definitions set out in Article 2 of Directive 1999/31/EC [39, European Commission, 1999] on the landfill of waste should be used (see below).

Article 2 of Directive 1999/31/EC [39, European Commission, 1999]
Definitions
For the purposes of this Directive:

(a) 'waste' means any substance or object which is covered by Directive 75/442/EEC;

(b) 'municipal waste' means waste from households, as well as other waste which, because of its nature or composition, is similar to waste from household;

*(c) **'hazardous waste'** means any waste which is covered by Article 1(4) of Council Directive 91/689/EEC of 12 December 1991 on hazardous waste*[1]

*(d) **'non-hazardous waste'** means waste which is not covered by paragraph (c);*

*(e) **'inert waste'** means waste that does not undergo any significant physical, chemical or biological transformations. Inert waste will not dissolve, burn or otherwise physically or chemically react, biodegrade or adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm human health. The total leachability and pollutant content of the waste and the ecotoxicity of the leachate must be insignificant, and in particular not endanger the quality of surface water and/or groundwater;*

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[1] OJ L 377, 31.12.1991, p. 20. Directive as last amended by Directive 94/31/EC (OJ L 168, 2.7.1994, p. 28)

Where the issue of waste appears to be highly relevant to the assessment, it may be necessary to establish a more detailed picture of the waste produced. It should be remembered that a detailed assessment will be difficult unless there is comprehensive information available about the waste arising, and its fate and effects in the environment. In most cases, it will be sufficient to apply the simple methodology described here. This simple approach does not, however, differentiate between a waste which is partially or totally recycled and one which is disposed of.

2.5 Guideline 3 – Calculate the cross-media effects

To assess the environmental effects for each of the alternative techniques under consideration, the methodologies set out below allow the different pollutants identified in the inventory to be collated into seven environmental themes. These themes are based on the environmental effects that the pollutants are most likely to cause. Collating the pollutants into themes allows different pollutants to be compared with each other. For each theme, the effect may be only or primarily in one medium, or there may be effects in more than one medium such as air or water. Care needs to be taken to take account of all effects in each case subject to any simplification used.
The themes are:

- **human toxicity**
- **global warming**
- **aquatic toxicity**
- **acidification**
- **eutrophication**
- **ozone depletion**
- **photochemical ozone creation potential**

These themes were carefully selected to give comprehensive coverage of the most relevant environmental effects whilst still ensuring that the assessment remains practical and relevant. Although the coverage is comprehensive, it has not been possible to define a methodology that covers every possible impact, such as the use of less hazardous substances and the possibility of accidents. Therefore, at all times, the user should be aware that there are environmental effects not accounted for here and should ensure that they are still considered in the final assessment.

During the development of this document, one further environmental theme (abiotic depletion) was considered. This would have given a measure of the resources used by the process and would have allowed consideration of the potential depletion of the earth's resources. Although abiotic depletion remains an important issue, there were significant concerns about the reliability of the factors that had been derived to describe it. There was also a feeling that it is unlikely to hold much weight against the other themes such as human toxicity or photochemical ozone creation potential. As a result, it was decided not to retain abiotic depletion in this methodology.

To calculate the cross-media effects, two different approaches are used for the various effects:

When assessing global warming effects, acidification, eutrophication, ozone depletion, and photochemical ozone creation potential, individual pollutants can be converted into an equivalent reference substance using multiplication factors. For example, a wide range of greenhouse gases can be expressed in carbon dioxide equivalents to describe their ‘global warming potential’ (GWP). Expressing individual pollutants in terms of a reference substance allows them to be compared directly and also allows a range of pollutants to be summed together to assess the significance of the total effect of the release. The mass emission of each greenhouse gas released from alternative options can then be multiplied against the GWP for that greenhouse gas and expressed as the equivalent effect of a mass of carbon dioxide. The individual greenhouse gases can thus be compared to see which has the greatest effect, and can also be summed to derive a total carbon dioxide equivalent for the option (in kg of carbon dioxide) using the equation below:

$$\text{Global Warming Potential} = \sum \text{GWP}_{(\text{pollutant})}\ x\ \text{mass}_{(\text{pollutant})}$$

For both the human toxicity and the aquatic toxicity themes, the mass of an individual pollutant emitted can be divided by the toxicity threshold of that pollutant to give a volume of air or water that would be needed to dilute the emission to safe levels when it is released. The volume of air or water can then be summed to derive a total theoretical volume of air or water that is polluted to its threshold, therefore allowing the alternative proposals to be compared.

$$\text{Toxicity} = \sum \frac{\text{mass of pollutant released}}{\text{toxicity threshold of the pollutant}}$$

The multiplication factors and toxicity thresholds used in both of the above approaches are derived from established methods that have been developed within recognised international forums. Where there are no established forums, the multiplication factors have been derived from current practices that are in use in Member States. The approach presented below for assessing a total human toxicity potential differs from the generality presented here and uses a dimensionless toxicity factor derived as lead equivalent in order to arrive at a hypothetical total.

The cross-media methodology described here can be used to assess alternative options that are under consideration as BAT. The methodology allows the environmental effect of each of the alternatives to be compared within the seven environmental themes.

In a local situation, there are likely to be further evaluations needed and it will also be necessary to ensure that the emissions from the proposal do not compromise environmental quality standards to ensure compliance with Article 10 of the Directive. When making such local decisions, more detailed information about the emissions and the local environment will usually be available and therefore a more detailed assessment can be carried out. This will typically include dilution or dispersion modelling of individual pollutants and an evaluation of their impact on the local environment. Additionally, there may also be issues such as noise, odour and vibrations that also need to be evaluated at an individual installation, but these cannot be easily assessed using this methodology.

The limitations of applying the cross-media methodology at an installation are discussed in this document and a screening tool that can be used to prioritise the pollutants of most concern is described in Section 2.6.4. This screening tool can be used to identify those pollutants of most concern, so that these can be assessed in more detail where appropriate. Methodologies that are used to determine permit condition in individual Member States are listed in Annex 13.

2.5.1 Human toxicity

Eliminating or minimising the possibility of human toxicity effects is a high priority for any proposed IPPC process. When operating an industrial process, the potential toxic effects will depend on the chemicals emitted, the mass of the chemicals released and the human toxicity of those chemicals. The methodology set out below uses the mass of each pollutant emitted and a toxicity factor for that pollutant to calculate a hypothetical total for comparing options. This approach also allows the user to identify those pollutants that have the most significant effect on the environment and therefore could be a priority for control.

2.5.1.1 Assessing the human toxicity potential of a proposal

A substantial body of legislation already exists which sets thresholds for pollutants in ambient air, as well as legislation for the protection of the health and safety of workers from the risks of exposure to chemicals in the workplace. The limits set in this legislation form a good basis for assessing the human toxicity potential of the alternative proposals under consideration. Strictly speaking, there is no agreed scientific way to add up different toxic effects, some of which have different time scales of effect and different health impacts. However, the approach presented in this document at least provides a common structure for making some sort of comparison between alternative scenarios. It assumes direct human toxicity by inhalation, simplifying the real exposure pathways for humans.

$$\text{human toxicity potential (kg lead equivalents)} = \sum \frac{\text{mass of pollutant released to air (kg)}}{\text{toxicity factor of the pollutant}}$$

Where:

human toxicity potential is an indicative number (in kg lead equivalents) for purposes of comparing options, the higher the number the greater the toxicity potential.

mass of the pollutant released in kg.

toxicity factor of the pollutant is a dimensionless number (see Annex 1)

2.5.1.2 Issues to consider

This methodology offers a basis for the user to compare alternative techniques that emit different pollutants, even when the pollutants have wide-ranging toxic effects. It also allows the user to identify which pollutants are of most concern in respect of their human toxicity potential. Toxicity is a complex issue and care needs to be taken in carrying out the assessment and when evaluating the results. The toxicity factors listed in Annex 1 have been derived from national OEL data and thus originally intended for different purposes.

This methodology is designed solely for comparing alternatives and is not appropriate for assessing the actual effects of emissions on the local environment from an individual installation. The physical properties of the pollutants and their fate and effects are not taken into account in this simplified calculation. The calculation establishes a number which can only be used for comparing alternative options.

Users need to understand the limitations with this simplified approach. It is a useful indicator for comparing options and for identifying those pollutants that are likely to cause the greatest concern, but it cannot be expected to do more than that. Further work is likely to be necessary to determine the actual environmental effects of the release of each pollutant in individual cases. If there are pollutants released that do not have a toxicity threshold listed in Annex 1, these pollutants should be identified separately and their likely effects discussed in the final report.

2.5.2 Global warming

The increasing quantity of so-called greenhouse gases in the atmosphere has the effect of trapping more of the sun's energy in the atmosphere. This effect is commonly referred to as 'global warming' or the 'greenhouse effect'. Predictions of the effects of global warming include increasing temperatures and changes to the earth's climate, which can then have implications for rainfall patterns, the availability of fresh water, changes in agricultural practices, rising seawater levels, etc. To slow down the effect of global warming, releases of polluting gases need to be reduced. The preferred option when deciding which alternative to implement for an IPPC process should, therefore, be chosen after taking into account the quantity of greenhouse gases released by each of the alternative techniques. The methodology set out below allows comparison of the global warming effects of the alternatives under consideration.

For a more detailed explanation and discussion of the scientific background and likely effects of global warming, readers are referred to the 'Third Assessment Report of the Intergovernmental Panel on Climate Change' (IPCC) [2, Intergovernmental Panel on Climate Change, 2001].

2.5.2.1 Assessing the global warming potential of a proposal

The polluting gases (i.e. greenhouse gases) that cause global warming have been the subject of a great deal of study by scientists from all over the world. The IPCC co-ordinates this work and has established 'global warming potentials' (GWPs) [2, Intergovernmental Panel on Climate Change, 2001] for a wide range of greenhouse gases. GWPs are an index for estimating the relative global warming contribution from the emission of one kg of a particular greenhouse gas compared to the emission of one kg of carbon dioxide (GWPs are expressed as kg of CO_2 equivalent).

The mass emissions of the individual pollutants that were collated for the inventory derived in Guideline 2, can be multiplied by their GWP and expressed as kg of carbon dioxide equivalent. The greenhouse gases released can then be collated and reported as a total carbon dioxide equivalent effect, using the following equation:

$$\text{global warming potential } (\text{GWP}_{(\text{total})}) = \sum \text{GWP}_{(\text{pollutant})}\ x \text{ mass of pollutant released}_{\ (\text{pollutant})}$$

Where:

GWP$_{(\text{total})}$ is the sum of the global warming potentials of the greenhouse gases released (kg CO_2 equivalent) for the option under consideration

mass of pollutant released $_{(\text{pollutant})}$ is the mass of the individual pollutant (greenhouse gas) under consideration, e.g. CO_2, CH_4, N_2O etc. (in kg).

The total global warming potential, expressed as carbon dioxide equivalent, for each of the alternative options can then be compared.

2.5.2.2 Issues to consider

The GWPs used here (Annex 2) are those for a 100 year time horizon, as published by the IPCC [2, Intergovernmental Panel on Climate Change, 2001] (Page 388). The 100 year time horizon has been selected as it allows a reasonable time-scale for the effect to be considered, but without the uncertainty associated with a longer time horizon. This is not the complete answer as many greenhouse gases are very long lived in the atmosphere. Users and decision-makers should be wary of selecting techniques that favour gases with lower global warming potentials but with greater longevity in the atmosphere than other options that release more short-lived gases. To help with the evaluation of the alternatives, the atmospheric lifetime of the greenhouse gases are also presented in Annex 2.

A recent EU Directive (2003/87/EC) establishes a scheme for greenhouse gas emissions trading within the Community which will amend Council Directive 96/61/EC (IPPC). This Directive aims to reduce greenhouse gas emissions, to meet the European Community's obligations under the 'United Nations Framework Convention on Climate Change' and the 'Kyoto Protocol'.

As a condition of introducing this scheme, there is a requirement that the IPPC permit will not set limits for the direct emissions of greenhouse gases from an installation that falls within the scope of the scheme. This is to ensure that there is no conflict between the two instruments and is without prejudice to any requirement pursuant to the IPPC Directive that relates to energy efficiency.

The purpose of the evaluation described here in the cross-media assessment is to decide which of the alternatives under consideration offers the highest level of protection for the environment as a whole. The GWP is a useful parameter for making this assessment, it is not suitable for use in developing or setting IPPC permit limits and there should be no conflict between the greenhouse gas-trading scheme and the cross-media assessment.

2.5.3 Aquatic toxicity

Discharges to aquatic environments can have a toxic effect on the plants and animals that live in that environment. The methodology set out below allows the decision-maker to assess the total aquatic toxicity effect of alternative options and then to rank those options based on the level of environmental harm that they may cause to the aquatic environment. The calculation used to determine aquatic toxicity is analogous to that used to determine the human toxicity potential of a proposal. The volume of water required to dilute the discharge to its toxicity threshold is calculated from known 'Predicted no effect concentrations' (PNECs) for the pollutants that are released.

2.5.3.1 Assessing the aquatic toxicity potential of a proposal

A substantial body of work has already been carried out to evaluate the toxicity of pollutants in the aquatic environment and as a result of this work, a wide range of pollutants have been characterised. The toxic effect of individual pollutants can be expressed as the 'predicted no effect concentration' (PNEC) mg/l of that pollutant, which is the level at which no toxic effect can be detected. By dividing the mass of a pollutant released by its PNEC, the user can calculate the theoretical volume of water that would be needed to dilute the discharge below its PNEC threshold. The volumes of water can then be summed for all pollutants, to calculate the theoretical volume of water needed to dilute the discharge to its 'predicted no effect concentration', using the formula below.

$$\text{Aquatic toxicity}\,(\mathrm{m}^3) = \sum \frac{\text{mass of pollutant released}_{\,(\text{pollutant kg})\, \mathrm{x}\, 10^{3}}}{\text{PNEC of the pollutant}_{\,(\text{mg/l})\, x\, 10^{-3}}}\; x\; 0.001$$

Where:

Aquatic toxicity is the quantity of water (m^3) required to achieve the predicted no effect concentration in water

The **mass of pollutant released** is the mass of the pollutant released into the aquatic environment in kilograms (multiplied by 10^3 to convert to grams)

The **PNEC of the pollutant** is the 'predicted no effect concentration of the pollutant in mg/l (see Annex 3). The factor of 10^{-3} converts the result to grams

The multiplication factor of 0.001 converts litres to m^3.

Predicted no effect concentrations for a wide range of aquatic pollutants and the methods that were used to derive them are presented in Annex 3.

2.5.3.2 Issues to consider

Calculating the volume of water that would be required to dilute a discharge to its PNEC in this way allows direct comparisons to be made between the alternative techniques under consideration. Annex 3 lists the PNECs of a range of substances. In cases where there is no PNEC listed, the user should ensure that these substances are clearly stated in the report, so that they can still be considered by the decision-maker in the assessment.

The calculation described above is the theoretical volume of water that would be required to dilute the discharge to its predicted no effect concentration threshold and does not represent the actual volume or concentration of polluted water that would be released from the process. In the real situation, it is also true that one litre of water will assimilate more than one pollutant. This methodology is useful when deciding in a general case, but it will not be sufficient for assessing the environmental impacts of an individual installation. When determining BAT at an installation, a more detailed assessment which might require detailed dilution modelling of individual pollutants is likely to be required. There may also be a need to consider the synergistic and antagonistic effects of combining pollutants. Issues such as the type of watercourse (river, lake, coastal water, etc.), the dilution available, ambient pollution levels, and the other uses of the watercourse (drinking water, swimming, fisheries, etc.), will all need to be considered when setting individual permit conditions.

This methodology is analogous to the human toxicity potential calculation. A short summary of the derivation procedure for PNECs is set out in the text at the end of Annex 3 and is similar to the approach used in the water framework Directive [10, European Commission, 2000]. At the time of development of this document, the list provided in Annex 3 is the most comprehensive listing of PNECs available, but care needs to be taken when interpreting the results. The derivation of PNECs for individual substances has been carried out by a variety of techniques where different safety factors are applied depending on the amount and type of information available on the toxic effects of the substance. Although this is a useful approach that fits in with the precautionary principle, the confidence limits that surround the numbers that have been derived are different in each case.

Work is continuing to establish PNEC values and the methodologies have been refined to the current methodology which is described in the technical guidance document [46, European Chemicals Bureau, 2003]. This guidance has been developed in support of Commission Directive 93/67/EEC [47, European Commission, 1993] on Risk Assessment for new notified substances, Commission Regulation (EC) No 1488/94 [48, European Commission, 1994] on Risk Assessment for existing substances and Directive 98/8/EC [49, European Commission, 1998] of the European Parliament and of the Council concerning the placing of biocidal products on the market.

As these assessments are carried out, the values derived by the European Chemicals Bureau from these procedures will replace those values listed in the table in Annex 3.

Whole effluent assessment may offer a useful means to address aquatic toxicity of mixtures of substances although care needs to be taken when using data from specific effluent streams in drawing sector relevant conclusion.

2.5.4 Acidification

The deposition of acidifying substances from acid gases in the air has been shown to cause a wide range of impacts. The effects include damage to forests, lakes and ecosystems, deterioration of fish populations and erosion of buildings and historical monuments. Although some acid gases come from natural origins, many originate from man-made sources such as transport, industrial processes and agricultural practices. Control of acidifying emissions has been a high priority in recent years and a great deal of work has been undertaken to improve the understanding of acid deposition mechanisms and to negotiate reductions of industrial acid gas emissions.

2.5.4.1 Assessing the acidification potential of a proposal

The gases that have the most significant acidifying effect are sulphur dioxide (SO_2), ammonia (NH_3), and oxides of nitrogen (NO_X).

‘Acidification potentials’ have been calculated to enable each pollutant to be expressed as a sulphur dioxide equivalent [15, Guinée, et al., 2001]. Calculation of the mass pollutant released multiplied by the acidification potential of the individual gases allows the total acidification effect of a proposal to be calculated and expressed as an overall sulphur dioxide equivalent.

The mass emissions that were compiled earlier for the inventory in Guideline 2 are summed using the formula:-

$$\text{Acidification} = \sum \text{AP}_{(\text{pollutant})}\ x\ \text{mass of pollutant released}_{\ (\text{pollutant})}$$

Where:

Acidification expressed as kg SO_2 equivalent

AP$_{(\text{pollutant})}$ is the acidification potential of the pollutant in sulphur dioxide equivalents (see Annex 4)

mass of pollutant released $_{(\text{pollutant})}$ is the mass of the pollutant released in kg

2.5.4.2 Issues to consider

The acidification potentials listed in Annex 4 are derived from [15, Guinée, et al., 2001] and are average values that are thought to be representative of Europe as a whole.

The detailed modelling behind the acidification potentials was carried out as part of the UNECE 'Convention on Long Range Transboundry Air Pollution'[2], which assesses the effects of acidification, eutrophication and ground level ozone. Land areas are split into individual area grid squares, which are then assessed for their susceptibility to acidification effects. This assessment is based on a range of factors, which include soil type, vegetation, buffering capacity and how close that area is to its critical load for acid deposition. Each individual square has a different acidification potential for individual polluting gases.

There are limitations with using this method, as not all of those pollutants that cause acidification have acidification potentials listed (for example, no values have been derived for HCl and HF). The acidification potentials listed are also underestimated as they do not take into account the acidifying impacts outside Europe. The effect of acidic emissions will also vary depending on where the emissions are released, the metrological conditions that disperse them and the sensitivity of the area where the emissions are finally deposited.

This approach is useful as an indicator when making decisions on the best option for the environment when the geographical location of a proposal is not known, as would be the case when determining BAT for a BREF. **Note that average acidification potential values are not appropriate for use when the location of the proposal is known**. When determining permit conditions for individual installations, there is likely to be a need to undertake detailed dispersion modelling to assess the effects of the emission. This is especially true where local air quality standards might be compromised because of existing background concentrations, or in areas where there are sensitive receptors.

2.5.5 Eutrophication

Eutrophication (may also be referred to as nutriphication) is the process of nutrient enrichment that occurs when pollutants can act as nutrients for photosynthetic organisms, and are directly or indirectly supplied to an ecosystem. The increase in nutrients causes some plant species to grow excessively and others to disappear. Eutrophication is especially a problem in coastal and inland waters, where blooms of algae can develop and lead to a depletion of oxygen in the water, affecting plants, fish and other life forms – these algae are often toxic to animals and humans. Excess nitrogen deposition on land can increase the nitrate concentrations in groundwater, which makes the water unpalatable. Eutrophication also causes nitrogen to leach from soils, increasing the acidification of surface and groundwaters.

2.5.5.1 Assessing the eutrophication potential of a proposal

The compounds that cause eutrophication are those that contain nitrogen and phosphorus. Using the life cycle assessment methodology, eutrophication potentials have been compiled for a range of compounds, so that total eutrophication effects can be calculated for the alternative proposals.

The eutrophication effect can be calculated using the formula:

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[2] A summary of the assessment methodology for the "United Nations Economic Commission for Europe" (UNECE) "Convention on Long-Range Transboundary Air Pollution" can be found at http://www.iiasa.ac.at/~rains/dutch/pollueng.pdf

$$\text{Eutrophication} = \sum \text{eutrophication potential}_{\text{(pollutant)}} \times \text{mass of pollutant released}_{\text{(pollutant)}}$$

Where:

eutrophication potential$_{\text{(pollutant)}}$ of the pollutant is expressed as kg phosphate ion equivalents PO_4^{3-} (see Annex 5)

mass of the pollutant released $_{\text{(pollutant)}}$ in kg is taken from the inventory that was compiled earlier in Guideline 2.

The eutrophication potentials presented in Annex 5 are taken from [11, Guinée, 2001].

2.5.5.2 Issues to consider

The eutrophication potentials presented here are based on the contribution that the pollutant released has on biomass formation, this is derived from the average composition (N/P ratio) of biomass.

The limitations in applying this methodology to an installation are similar to those described earlier for acidification. Although useful for making decisions in general cases, this approach is not suitable for assessing the eutrophication potential of emissions on the local environment for an individual installation. It ignores the local dispersion characteristics, the fate of the pollutant once released, the nature of the receiving environment and the sensitivity of the local environment to the individual pollutant released.

This methodology is based on the approach used in life cycle assessments. There are concerns about adding together emissions to air, water and land (i.e environmental effects in different environmental media), in that the scientific validity of doing so is dubious. Nevertheless, this approach does allow a quick and simple assessment of the eutrophication potential of the options to be carried out. Users should still be wary of this and where the results are not clear, there may be a need to break the pollutants fate down into more detail (and split emissions between air/water/land).

When determining the permit conditions for an individual installation, detailed dispersion modelling of individual pollutants (air/water/land) in the local environment are likely to be necessary.

2.5.6 Ozone depletion

The ozone layer is the layer in the stratosphere, which helps to protect animals and plants from the sun's UV radiation. Ozone depletion is the effect of the stratospheric ozone layer being broken down by chemical reactions with polluting gases released from human activities. These polluting gases include chlorofluorocarbons, halons and other gases that may be released from IPPC processes. Depletion of the ozone layer can cause damage to crops and health effects such as eye cataracts and skin cancers in both humans and animals.

To reduce ozone depletion, the strategy is to reduce emissions of the polluting gases that cause the breakdown of the ozone layer.

2.5.6.1 Assessing the ozone depletion potential of a proposal

To help with the strategy of reducing the emissions of polluting gases, the relative stratospheric ozone depleting effects of a wide range of gases have been evaluated. The results of the research carried out have been brought together by the World Meteorological Office [3, World Meteorological Office, 1998]. The 1987 Montreal Protocol on substances that deplete the ozone layer [31, United Nations Environment Programme, 1987] lists multiplication factors, so that a range of gases can be multiplied by their 'ozone depleting potential' and then expressed as CFC-11 equivalents.

The ozone depleting potentials of a range of gases can then be added together and expressed as an ozone depleting potential by using the formula:

$$\text{Ozone depletion} = \sum \text{ozone depletion potential}_{\text{(pollutant)}} \times \text{mass of pollutant released}_{\text{(pollutant)}}$$

Where:

Ozone depletion is the sum of the ozone depleting potentials for the technique under consideration in kg CFC-11 equivalents

ozone depletion potentials are listed in Annex 6.

mass of the pollutant released$_{\textbf{(pollutant)}}$ is the mass of the pollutant in kg

2.5.6.2 Issues to consider

The effect on the ozone layer and the theory behind ozone depleting potentials is relatively well understood and internationally accepted. Ozone depletion is not an issue that has local effects and although minimising releases of the chemicals that cause the problem remains a high priority for the permit, when evaluating an individual installation, this topic is unlikely to be assessed in any more detail than that presented here.

2.5.7 Photochemical ozone creation potential

Ozone at lower elevations, also called tropospheric ozone or ground level ozone, is a pollutant. It is formed by a complicated series of chemical reactions, initiated by sunlight, in which nitrogen oxides (NO_X, where $NO_X = NO + NO_2$) and volatile organic compounds (VOCs) react to create ozone. These chemical reactions are not instantaneous, but take place over several hours or even days depending on the compound. Once ozone has been produced it may persist for several days.

Consequently, ozone measured at a particular location may have been caused by VOCs and NO_X emissions many hundreds or even thousands of kilometres away, and may travel further still for similar distances. Maximum concentrations, therefore, generally occur downwind of the source areas of the precursor pollutant emissions. In urban areas, where concentrations of traffic emissions may be high, nitric oxide (NO) from exhaust emissions may react with ozone to form nitrogen dioxide (NO_2), thereby reducing ground level ozone concentrations. However, as the air movement carries the primary pollutants away, more ozone is generated and concentrations rise in downwind areas [7, European Commission, 1999].

Tropospheric ozone can cause damage to human health, such as respiratory difficulties in sensitive people, damage to vegetation and corrosion to materials. The approach for controlling levels of ground level ozone is to reduce the levels of NO_X and VOCs released from industrial processes.

2.5.7.1 Assessing the photochemical ozone creation potential of a proposal

The ozone creation potential of individual VOCs depends on their structure and reactivity. In order to evaluate the total effect of releasing different VOCs, the UNECE ‘Protocol to Abate Acidification, Eutrophication and Ground level Ozone’ convention[3] proposed the concept of using photochemical ozone creation potentials (POCPs).

The use of POCPs allows a range of VOCs to be expressed as ethylene equivalents and summed using the formula:

$$\mathrm{POCP}_{(\mathrm{total})} = \sum \mathrm{POCP}_{(\mathrm{pollutant})} \times \text{mass of pollutant released}_{\,(\mathrm{pollutant})}$$

Where

$POCP_{(total)}$ is the Photochemical ozone creation potential expressed as kg ethylene equivalents

$POCP_{(pollutant)}$ is the photochemical ozone creation potential of the individual pollutant

mass of pollutant released is the mass of the pollutant which has a photochemical ozone creation potential that would be released in kg (from the inventory in Guideline 2).

POCPs have been established for a number of VOCs and other substances, and are listed in Annex 7.

2.5.7.2 Issues to consider

The reactions involved in photochemical ozone creation are complex, and are difficult to model accurately because they involve the interaction of a range of chemicals, sunlight and meteorological conditions. There is considerable uncertainty over individual POCP values and prediction of the concentrations of ozone that will be formed is difficult. Even so, the approach outlined here is a useful technique for comparing the effects of alternative proposals.

There is also a need to take into account the requirements of Directive (1999/13/EC) on the need to limit emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations [44, European Commission, 1999], which sets limit values to reduce VOC emissions.

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[3] More information on the convention can be found at http://www.unece.org/env/lrtap/multi_h1.htm

2.6 Guideline 4 – Interpret the cross-media conflicts

Where an obvious conclusion has become apparent from the assessments carried out in the previous guidelines, then providing a sensitivity analysis has been carried out on the key assumptions, the recommendation can be stated with the justification built on the findings from the assessment. If no obvious conclusion has been reached, due to apparent cross-media conflicts, then there may be a need to present the results in a transparent way so that the decision maker can evaluate the relative merits of the alternatives under consideration.

In order to compare the options, and the results of the evaluations carried out so far, three possible approaches are set out below. These approaches may be used individually or they may be used together:

- the first approach is a simplistic approach of comparing the results from each of the environmental themes calculated previously
- the second is more complex and allows the effects calculated so far to be compared against the European totals for each of the environmental themes
- the third approach allows for individual pollutants to be compared with the European pollutant emissions register.

The guidelines described so far are useful, in that they set out the information in a transparent way so that the decision-maker can compare the alternatives fairly. At this stage, there is a need to question the accuracy of the data and carry out a sensitivity analysis which can be based on the accuracy of the factors that have been used. At this stage, there may also be a need to consider the relative priorities that can be attached to the environmental themes or even individual pollutants. The methodology cannot make the decision, it is just a tool that allows the user to set out the issues so that the decision maker can consider the alternatives fairly.

None of the methodologies set out below are perfect and expert judgement will be necessary to complete this evaluation. Issues that might be important (particularly in the local situation [18, UK Environment Agencies, 2002],) [62, Federal Environmental Agency Germany, 1999] include *inter alia*:

- the contribution to an environmental benchmark: if the process contribution of a substance is very low in comparison to its benchmark then this will be less important in the decision-making process than when the contribution is high
- environmental quality: where the existing environmental quality is poor, greater importance (particularly in the more local situation) may be placed, in the assessment of relative performance, on reducing the contribution from the process to that aspect of the environment
- the presence of sensitive receptors: greater importance may be given where there is local proximity of receptors or habitats that are particularly sensitive to a substance or its impacts
- the nature of the effects: long-term irreversible effects may be considered to be worse than short-term, reversible ones
- highly persistent, bioaccumulative, toxic and carcinogenic substances which are a priority due to their potential for long-range and transboundary effects.

2.6.1 Simple comparison of each of the environmental themes

Using the values calculated in Guideline 3, a simple comparison can be carried out to see which of the alternatives is the best performer for each of the environmental themes. This is a quick and simple assessment, but does not give any indication of the magnitude of the differences between each of the alternatives; therefore, it will still need some discussion as to how significant the differences between the alternatives are. As mentioned above, a sensitivity analysis on the component factors increases the objectivity in assessing alternatives.

2.6.2 Normalisation to European totals

The effects from alternative options can be normalised against a common reference value. The common reference might be, the contribution that the alternative would make to a specific total European load (for example, the contribution that the alternative under consideration makes to the European total emissions of 4.7 x 10^{12} kg carbon dioxide equivalents). This can be used as a mechanism for assessing the significance of the different environmental effects from the alternative options. (This is analogous to the 'contribution analysis' step in life cycle assessment.)

The greatest difficulty with this procedure is establishing the common reference point to normalise against. Some work has been carried out to establish common references for total European loads and those that have been derived for the themes used in the cross-media methodology are listed in Table 2.2 below.

Environmental Theme	**Units**	**Total European load (1994/1995)**
Energy[1]	MJ/year	6.1 x 10^{13}
Waste[1]	kg/year	5.4 x 10^{11}
Human toxicity		Not available
Global warming (100 year time horizon) [2]	kg CO_2 equivalent/year	4.7 x 10^{12}
Aquatic toxicity		Not available
Acidification[2]	kg SO_2 equivalent/year	2.7 x 10^{10}
Eutrophication[2]	kg PO_4^{3-} equivalent/year	1.3 x 10^{10}
Ozone depletion (infinite time horizon) [2]	kg CFC-11 equivalent/year	8.3 x 10^{7}
Photochemical ozone creation potential[2]	kg ethylene equivalent/year	8.2 x 10^{9}

[1] Based on **[9, Blonk TJ et al, 1997]** – waste would be better divided into hazardous, non-hazardous and inert figures if data available
[2] Based on **[8, Huijbregts, et al., 2001]**

Table 2.2: Total European Loads

Users should take care when using this methodology. The European totals listed above carry significant uncertainties and so the conclusions that can be drawn from them should be considered with caution. Thus it is recommend to only consider differences in order of magnitude.

2.6.3 Normalisation against European pollution emission register data

For the purpose of this methodology, known emission levels of different pollutants resulting from the use of different techniques can be compared to the total emissions from IPPC installations within the EU as reported to the European pollution emissions register (EPER[4]). The comparison can either be carried out with the aggregate figures for all IPPC sectors, or, more appropriately, with the aggregate figures for the specific IPPC sector in question. It can be carried out using either the EU-wide data or the country wide data. The following simple example can serve as an illustration of how emissions could be normalised.

One technique might lead to emissions of methane to air corresponding to 0.01 % of the total methane emissions to air in the (EU) sector and at the same time, a level of emissions of phenols to water corresponding to 1 % of the total phenol emissions to water in the (EU) sector. Similarly, a second technique might lead to emissions of methane to air corresponding to 0.1 % of the total methane emissions to air in the (EU) sector and emissions of phenols to water corresponding to 0.001 % of the total phenol emissions to water in the (EU) sector. Compared to the first technique, the second thus leads to 10 times higher relative methane emissions to air but 1000 times lower relative phenol emissions to water.

When using EPER data, it should be kept in mind that the data will inevitably not be 100 % accurate and will carry similar levels of uncertainty as the total European loads. This is why it is recommended to only consider differences in orders of magnitude.

2.6.4 Screening local environmental effects

Article 9 (4) and Recital 18 of the Directive provide that it is for Member States to decide how to take account of local environmental conditions. Article 3 of the Directive does require that installations are operated so that no significant pollution is caused. Determination of BAT for a sector cannot take into account detailed local issues and this section describes a way in which local significance can be estimated. Across Europe, there are significant variations in receiving environments, in local ambient concentrations of pollutants and in environmental priorities. For any individual process, the assessment of likely impacts of the proposal may require detailed dilution and dispersion modelling of individual pollutants. The dilution factors below can be used as a quick screening tool to evaluate which pollutants might need to be modelled in more detail in the local situation. Different techniques may be equally appropriate depending on the procedures and environmental quality standards that individual Member States have in place.

The dilution factors listed below are considered to offer sufficient protection in many cases. [18, UK Environment Agencies, 2002] [45, Goetz, et al., 2001] Nevertheless, there may be local situations, where an environmental quality standard for a pollutant is already being exceeded or is close to its threshold. In these cases, a detailed assessment of that pollutant may still be appropriate to assess the likely impact. There may also be cases where there is a need to consider the dispersion and impacts of long range emissions. Alternatively, the discharge from the IPPC process might pass through a water treatment facility before discharge to the watercourse, in which case it is the likely impact of the final discharge to the watercourse that needs to be considered. Whilst this section focuses on emissions to air and water, other issues such as odour and noise may be important at the local level. Ultimately the decisions as to what approach is used and if detailed modelling is appropriate, will need to be made locally.

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[4] On 17 July 2000, the Commission adopted Decision 2000/479/EC on the implementation of a European Pollutant Emission Register (EPER) according to Article 15(3) of the IPPC Directive.

Information on emissions of 50 pollutants and pollutant groups above certain fixed thresholds from facilities covered by the IPPC Directive will be available in the EPER. For the first time in June 2003, Member States were obliged to report to the Commission data on total annual emissions in 2001 (optionally 2000 or 2002). For further information about the pollutants that are covered by the EPER, see Commission Decision 2000/479/EC (http://www.europa.eu.int/eur-lex/en/lif/reg/en_register_151020.html).

The Commission, assisted by the European Environment Agency, make the data in the EPER register publicly accessible by dissemination of the reported data on the Internet, including disclosure of site-specific information of relevant polluting sources as well as various aggregated figures. (http://www.eper.cec.eu.int),

Screening local environmental effects

To screen whether environmental effects are likely to be significant at the local level, the following methodology can be used as a simple guide.

$$\text{Dispersed Concentration} = \frac{\text{emission concentration (mg/m}^3\text{or mg/l)}}{\text{dilution factor}}$$

In the absence of actual typical data, standard dilution factors can be used for such screening:

- **for discharges to water, a dilution factor of 1000**
- **for discharges to air, a dilution factor of 100000 (based on discharge from a chimney stack from, e.g. combustion plants)**

The resulting dispersed concentration can then be compared to the relevant environmental quality standard, or similar benchmark.

If the release does not contribute to a dispersed concentration of greater than 1 % of the relevant environmental quality standard, or a similar benchmark, then the emission is sometimes regarded as insignificant (see text above this box).

2.7 Conclusions on cross-media effects

The methodologies outlined above allow comparisons to be made between alternative process options. The guidelines are designed to make the evaluation as transparent as possible. To ensure that the assessment is efficient, there has been a need to simplify the methodologies. A balance has, therefore, been struck between the complexity of the assessment and the resources required when using it. Users need to understand this and ensure that the final decision is not distorted because of these simplifications.

The cross-media guidelines should be used with caution; limitations with the methodology have been highlighted in the text. One of the biggest concerns is the choice of multiplication factors, as these can skew the results significantly. Confidence in the calculated results diminishes as multiplication factors are used and different pollutants are aggregated. Concerns about the derivation of multiplication factors have also been identified in the text. As each step introduces further uncertainty, the error bands surrounding the numbers accumulate.

Although the cross-media evaluation described here is comprehensive, it is neither exhaustive nor exclusive as there may be other additional factors that might be important in individual cases. There may for instance be pollutants released from the process that are not captured by the environmental themes described here. There may be other pollutants that, although they have an effect within an environmental theme, there are no multiplication factors that have been derived for them. The Directive requires the consideration of issues that could not be incorporated in the assessment, such as noise, vibration, odour, risks to the environment, etc. The user should be vigilant and ensure that any other important environmental effects that might occur as a result of applying a proposal are still considered in the assessment.

Any issues not considered fully or any concerns about the validity of the data need to be understood both by the user of the cross-media methodology and the decision-maker. Expert judgement will be required in evaluating the results of the assessment and determining which option is preferred from an environmental point of view. The user will also need to ensure that transparency is always maintained throughout the assessment and in the decisions taken.

3 THE COSTING METHODOLOGY

Once the options have been ranked according to environmental performance, the option that results in the lowest impact on the environment as a whole will usually be BAT, unless the economic considerations mean that it is not available [18, UK Environment Agencies, 2002]. After the cross-media assessment, there may be a need to compare the costs of the alternative techniques. In order for the alternatives to be treated consistently, it is important that the cost information, which may have been derived from different sources, is collected and handled in the same way. The rules set out below help to set a framework under which the costs can be gathered, attributed and processed transparently, so that fair comparisons can be made.

When using cost data, it is important to remember that accounting conventions vary across Europe and between companies. As a consequence, it can be very difficult to make fair comparisons between cost information for installations, especially when those costs have been derived from different sources or have been manipulated in different ways. The methodology described below is based on the work carried out by the IPPC TWG on economics and cross-media effects and reported in the document ‘Costing Methodology for BAT Purposes’ [4, Vercaemst, 2001]. This work was based on guidance published by the European Environment Agency - ‘Guidelines for defining and documenting data on costs of possible environmental protection measures’ [6, European Environment Agency, 1999] and on the VDI - 3800 Guidelines [36, VDI, 2000].

The costing methodology sets out a framework which allows the cost data for installing, operating and maintaining a process or technique to be gathered and processed. Adopting a consistent approach in this way allows the alternatives to be compared, even when the data is derived from different companies, different industries, different regions or different countries. The steps involved in this chapter are shown schematically in Figure 3.1 below.

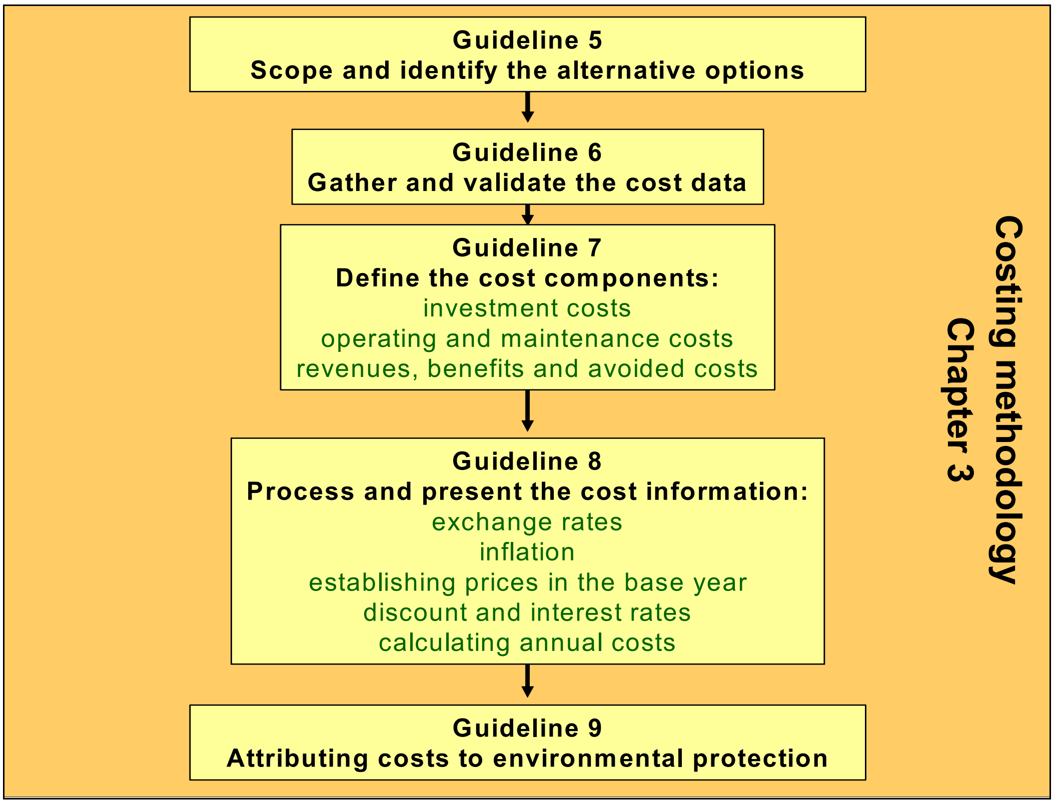

Figure 3.1: The steps involved in the costing methodology

The steps involved in this chapter are:

1. Guideline 5 - Scope and identify the alternative options: This guideline is analogous to Guideline 1 in the cross-media methodology.

2. Guideline 6 - Gather and validate the cost data: This guideline leads the user through the steps necessary to gather and validate the cost data and deal with any uncertainties that the data might have.

3. Guideline 7 - Define the cost components: This sets out the cost components that need to be included or excluded from the assessment. When assessing the results, it is useful for the decision-maker to be able to understand how the costs were made up and whether the costs are attributed to the cost of the installation or whether they are operating or maintenance costs. The guideline requires that the costs are presented as transparently as possible.

4. Guideline 8 - Process and present the cost information: This sets out the procedures for processing and presenting the cost information. There is a need to take account of interest rates, discount rates, the economic lifetime of the equipment and any scrap value that equipment might have. Where possible, the costs should be presented as an annual cost; the calculations required to establish this are explained in Section 3.4.

5. Guideline 9 – Attributing the costs to environmental protection. This sets out how costs for environmental protection can be distinguished from costs for things like process improvements or process efficiencies.

The aim of this methodology is to make the assessment as transparent as possible. The costs should be broken down into a sufficient level of detail that shows which costs are attributed to investment expenditures and which are attributed to operating and maintenance costs. The methodology offers the user some flexibility to choose the interest and discount rates that best fit the application under consideration. However, the choice of interest and discount rates need to be justified and those rates then applied in the same way to all the alternatives, so that they can all be compared fairly. Applying these guidelines should allow both the user and the decision-maker to compare the alternative options in a transparent and equitable way. In practice, cost data are often estimated and seldom available broken down into detailed components or to the level where changes in annual costs year on year can be made with any degree of accuracy.

3.1 Guideline 5 – Scope and identify the alternative options

Scoping and identifying the alternative options is analogous to the approach set out in Guideline 1 of the cross-media methodology. In many cases, the descriptions derived for Guideline 1 will be sufficient, but it is likely that there will now be further information available to supplement the description. Issues such as the technical characteristics of the alternatives, including the (expected) technical and economic lifetime of the equipment, and operational data such as energy use, use of reagents, maintenance, water consumption, etc. will also have been established by now.

At this stage it should also be possible to describe the environmental benefit that will be realised by implementing the technique. It is useful to express this environmental benefit as a comparison with a base case, or the expected efficiency of the technique. Efficiency is often expressed as a percentage, e.g. 'an incinerator reduces organic emissions by over 95 %'. However, this is not always helpful, as it does not describe what the uncontrolled emissions were. Therefore, it is more useful to record the efficiencies in two ways:

1. as a base case emission or emission factor for the installation together with a percentage efficiency for the technique; e.g. 'for a process emitting over 1000 mg of solvent per m^3 of exhaust air, an incinerator will have a solvent destruction efficiency of at least 95 %'.

AND/OR

2. as performance data (emissions or emission factors) for the installation after implementation of the measure e.g. 'for a solvent emitting process fitted with an incinerator, the emission is normally 10 mg of solvent per m^3 exhaust air, or less'.

The first approach allows the estimation of both the emission abatement and the remaining emissions, whereas the second approach only provides information on the remaining emissions. There should be no ambiguity in the description as this forms the basis for gathering the cost data. It is useful to be as specific as possible, particularly when describing the technique and the environmental benefits that it will deliver.

3.2 Guideline 6 – Gather and validate the cost data

There are many data sources from which cost data could be derived and the applicability, timeliness and validity of the data may differ depending on the source. Both the user and the decision-maker need to know about any concerns that could effect the validity of the data as they may have a bearing on the conclusions that are drawn from the assessment, and thus, on the final decision that is taken. The aims of Guideline 6 are to identify the sources of the cost data used, to establish how these are referenced, and to advise on how to deal with any uncertainties in the data.

Data are always originally derived to serve a specific purpose and are, therefore, likely to include some element of subjectivity which must be borne in mind when using data for a purpose other than the one it was originally intended for. There may also be different accounting conventions and reporting formats used by different companies and applied in different countries. There may even be claims of commercial confidentiality for data, which will need to be handled with some sensitivity. Dealing with confidential information also makes the assessment more difficult to verify. All of these issues can cause difficulties when the user or decision-maker is trying to validate the figures or make meaningful comparisons.

Throughout this section where reference is made to costs, it should be borne in mind that any cost saving also needs to be taken into account.

3.2.1 Sources of cost data

Cost data can be obtained from a variety of sources but whatever the source, the user needs to think critically about the validity of the data. Costs may either be over or under estimated [12, Pickman, 1998]. The data will also have a 'shelf-life', as costs and prices can vary over time. For example, the price of a technique could increase with inflation or, it could fall as the technology changes from an experimental to a mass-produced technique. Possible sources of cost data include:

- industry, e.g. construction plans, documentation of industrial projects, permit applications
- technology suppliers, e.g. catalogues, tenders
- authorities, e.g. the permitting process (for a new or updated permit)
- consultants
- research groups, e.g. demonstration programmes
- published information, e.g. reports, journals, websites, conference proceedings
- cost estimates for comparable projects in other industries or sectors.

To improve validity, the user should gather cost data from a number of independent sources, if possible. The source and the origin of all data should be recorded. This will allow the data to be traced and validated at a later date if necessary. If the data source is a published report or database, then a standard bibliography will normally suffice for this purpose. If the data source is a verbal or some other undocumented communication, this should be clearly stated and the source and date recorded.

The user should strive to identify and use the most recent valid data available. The year to which the cost data apply and the currency exchange rate applied should always be stated. The costs should be reported as 'actual expenditure', that is the costs need to be reported in the year in which the actual expenditure was or will be incurred, even if they are subsequently adjusted to take account of time. This ensures transparency and allows the users to manipulate the data in different ways if necessary. Guidance on how to adjust cost data to take account of time, inflation and on the use of discount rates, are set out in Guideline 8.

3.2.2 Documenting data uncertainty

As a minimum, the assessment should include a discussion of the key uncertainties related to the data. In some cases, there may be a number of uncertainties associated with cost data and the operating performance of the proposed technique. These uncertainties might be due to a lack of available information, or possibly because the key assumptions behind the cost data are not always transparent.

The approach previously described in the cross-media assessment (Section 2.4.1) is a useful guide to dealing with uncertainties in the data. In many cases, there will be quantitative measures or a range of uncertainty that can be attributed to the data. Where this information is available it should be recorded, so that it can be used later in the assessment to establish confidence in the upper and lower ranges by carrying out a sensitivity analysis. Where quantitative information on the data is not available, a data quality rating system can be used to give a qualitative indication of the reliability of data. The rating score gives a rough guide to the user or reader as to the confidence that they can have in the data and helps to give some indication of how thorough the sensitivity analysis needs to be.

3.2.3 Summary of guideline 6

In the context of this guideline, the following aspects are considered important:

- the origin of the information should be stated clearly (year and source)
- the data should be as representative as possible
- cost data should be gathered from a number of (independent) sources
- the source and origin of all data should be recorded as precisely as possible
- the most recent valid data available should be used
- the year of the cost data and the currency exchange rate applied should always be stated
- costs should be reported as actual expenditure
- if possible, quantitative ranges should be provided to describe the validity of the data. If this is not possible, a qualitative indication could be used.

3.3 Guideline 7 – Define the cost components

To help with comparison of the data, the cost components that have been included in the cost data should be clearly stated when the assessment is reported. The aim of this guideline is to define which cost elements should be included or excluded and also to give guidance on how those elements that are included should be reported. The breakdown of costs into its components, e.g. investment, operating and maintenance costs, etc., is essential for the transparency of the process, although it is often difficult in practice to split costs between process and environmental.

The following is a useful hierarchy for the level of disaggregation of the cost data:

(1) Total **investment expenditure**, total annual **operating/maintenance costs** and total annual **benefits/revenues** should all be reported separately.

(2) **Investment expenditure** should be split between pollution control equipment expenditure and process control or installation expenditure.

(3) As far as possible, annual **operating and maintenance costs** should be split between energy, materials and services, labour, and fixed operating and maintenance cost.

All costs should be measured in relation to an alternative. The alternative is usually the existing situation, or the ‘base case’ in which the environmental protection technique has not been installed. The base case will have been established from the cross-media methodology and the costs of the alternatives will be expressed in relation to the base case. For new plants, the costs for all of the options will need to be declared.

3.3.1 Check-list of cost components

Disaggregating the cost data between the individual cost components is useful and should be carried out as much as possible. The three checklists presented below list some of the cost components that are most useful for the assessment. The checklists cover ‘investment costs’, ‘operating and maintenance costs’ and ‘revenues, avoided costs and benefits’. These checklists are not exhaustive and other components might be important in individual cases.

Investment costs

Installation expenditure:

It would be useful if the costs are disaggregated into such a level of detail that the following are known:

- project definition, design, and planning
- purchase of land
- general site preparation
- buildings and civil works (including foundations/supports, erection, electrical, piping, insulation, painting, etc.)
- engineering, construction and field expenses
- contractor selection costs and contractor fees
- performance testing
- start-up costs
- cost of working capital
- decommissioning costs[5].

Note: Investments may also involve the loss of production during a certain period of time, for example, during change-over, or temporary disruptions to production. This often occurs when implementing measures that are integrated into the process. These costs may be specific to individual cases and so they need to be shown separately from other costs. There may be opportunities to minimise the loss of production by planning plant modifications so that they coincide with a scheduled maintenance period. If this can be undertaken then there is an opportunity to keep costs down and it is, therefore, useful to have these costs listed separately, so that they can be evaluated. Where known, the time taken to install the abatement equipment should also be stated.

Pollution control equipment expenditure:

- equipment costs
- primary pollution control devices
- auxiliary equipment
- instrumentation
- any associated freight of equipment
- modifications to other equipment.

Contingency allowance:

In estimates of investment expenditure, a sum of money, or ‘contingency allowance’ is sometimes included to cover expenses that cannot be estimated precisely. These are things that are known will happen but cannot be defined in such detail that they can be valued and added into the estimate. As a project progresses, and the project definition becomes more detailed the contingency will reduce. The size of the contingency allowance is a matter of judgement and experience and will depend primarily on the degree of technical confidence that can be placed in the design. It is normally quoted as a percentage of the investment expenditure. Any contingency must be quoted separately and to ensure transparency, if different contingency rates are quoted for the alternative techniques under consideration, these differences will need to be justified.

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[5] Where end-of-life and decommissioning costs are included, these should usually be discounted to a present value and the residual value of the equipment should be deducted from the costs. It is usually appropriate to assume a lower discount rate to these costs than that assumed for the rest of the project. This is because the uncertainty associated with estimates of decommissioning costs is such that they are more likely to be underestimated than overestimated, which would lead to bias in the cost assumptions.

Operating and maintenance costs

Energy costs:

- electricity
- petroleum products
- natural gas
- coal or other solid fuels.

Note: The users of cost data and the decision-makers need to understand the physical materials that the costs refer to and their prices. For example, the report should quantify the electricity used, its unit price, as well as the overall cost, e.g. ‘the electricity cost is EUR 4000 per year (100000 kilowatt-hours per year at a price of EUR 0.04 per kilowatt-hour)’. The grade of fuel should also be given where known.

Materials and services costs:

- replacement parts
- auxiliaries, such as chemicals, water
- environmental services, such as waste treatment and disposal services.

Note: It can be useful to report information that qualifies the amounts as well as the unit cost, such as any assumptions about the frequency of replacement, e.g., ‘over a 10 year period the catalyst may be changed three times’.

Labour costs:

- operating, supervisory, maintenance staff
- training of the above staff.

Note: Labour costs are calculated by multiplying the number of man-years per year by the gross annual salary related costs for an employee in the relevant sector. Where the labour required is not known, these costs (including the overheads discussed below) can be estimated as a percentage of the purchase price of the equipment and associated costs. VROM [38, VROM, 1998] suggest 3 – 5 %, but UNICE report 20 – 25 % [37, UNICE, 2003]. These are very approximate figures and as such the basis for the percentage selected should be clearly stated in the assessment.

Fixed operating/maintenance costs:

- insurance premiums
- license fees
- emergency provisions
- other general overheads (e.g. administration).

Note: If the labour costs for operation and maintenance are known, the overhead costs can be estimated as a percentage of the labour costs; for example, VROM [38, VROM, 1998] suggest 10 - 20 % of the labour costs, UNICE report 50 % of the labour costs [37, UNICE, 2003]. Again this is a very approximate figure and the basis for the percentage selected should be clearly stated in the assessment.

Subsequent costs:

The implementation of a new technique can lead to changes in the production process, which again might lead to increasing costs, for instance, a drop in system effectiveness or inferior product quality. Derived costs should be assessed as far as possible and clearly identified when reporting the results [36, VDI, 2000].

Revenues, avoided costs and benefits

Where the alternatives under consideration can also deliver non-environmental benefits, revenues or can lead to some costs being avoided, then these should be reported separately from investment expenditures or operating and maintenance costs.

Examples of revenues, avoided costs and subsequent benefits [6, European Environment Agency, 1999] are:

Revenues:

- sale of treated effluent for irrigation
- sale of generated electricity
- sale of ash for building materials
- the residual value of equipment (see above).

Avoided costs:

- savings on raw materials
- savings on auxiliaries (chemicals, water) and services
- savings on energy use
- savings on labour
- savings on the monitoring of emissions
- savings on maintenance
- savings on capital due to more effective use of plant
- savings on disposal costs.

It is recommended that these additional savings should also be stated in physical terms, such as:

- the amount of energy saved
- quantity of useful by-product recovered and sold
- number of man-hours saved.

Subsequent benefits:

The implementation of a new technique can lead to changes in the production process, which again might lead to lower costs, for instance, a rise in system effectiveness or improved product quality. Derived benefits should be assessed as far as possible and clearly identified when reporting the results [36, VDI, 2000].

3.3.2 Costs that need to be identified separately

Taxes and subsidies - Economists sometimes refer to taxes and subsidies as transfer payments, because they do not represent an economic cost to society as a whole, but merely transfer resources from one group in society to another. (Some examples of these taxes are purchase taxes, property taxes, fuel taxes or taxes on other operating materials, value added tax, etc.). They are normally excluded from calculations of ‘social costs’ (cost evaluations of the impacts on society as a whole), but when considering the 'private costs' (the costs to an operator), these costs can be very relevant.

Taxes and subsidies should be identified separately to ensure that the evaluation is transparent (this information may already have been included in the source from which the data were taken).

Indirect costs - Indirect costs are those costs that can be attributed to changes in demand in the market and any knock-on effects such as changes in output and employment. These should be excluded from the cost evaluation. If this is not possible (because they are included in the source information), the indirect costs should be identified and reported separately.

External costs – External costs should be excluded. These costs do not form part of the costing methodology and are not used to determine the costs of the alternative techniques under evaluation. The definition and use of external costs is discussed later in Chapter 4.

3.3.3 Scale factors for plants

Where costs are known for one size of plant and an estimate wanted of the costs for another size of plant taking account of the possible economies of scale, this can be carried out using the 'scale exponent' method. The 'scale exponent' method may be used to scale up (or scale down) the cost of individual plant items as well as whole plants. The methodology is explained below.

The scale exponent method

For calculating the costs of a plant built to a different scale to the original quotation, the equation below gives an approximate value.

In the equation, the cost of a plant of scale **x** is $\mathbf{C_x}$, (scale can be a measure of size or of throughput, but has to be the same units for both plants) and the cost of a plant of scale **y** is $\mathbf{C_y}$, which can be calculated using the formula.

$$Cy = Cx\left[\frac{y}{x}\right]^{e}$$

Where:

Cy: cost of plant y
Cx: cost of plant x
y: scale of plant y (whether it be size or throughput)
x: scale of plant x (whether it be size or throughput)
e: rough approximation factor (see below)

The value of the exponent '**e**' varies from one plant to another as well as from one type of equipment to another. However, the averaging effect on the total cost of a plant containing a variety of items is such that a value of 0.6 for '**e**' is roughly correct when the throughput is used as the scaling parameter (as is the case for most refining and petrochemical process plants).

If plant capacity is increased by raising the output of the main unit, a value for '**e**' of between 0.6 and 0.7 is appropriate.

For very large plants, where items of equipment have to be duplicated to increase the scale, the exponent may be higher, for example, if output is raised by increasing the number of units then a value of '**e**' of between 0.8 and 1 may be more appropriate.

Users and decision-makers need to understand that this is an approximation only. Again the user will need to state clearly when this methodology has been applied.

3.3.4 Summary of Guideline 7

The following points are a summary of the costs that should be defined and reported in the assessment:

1. costs should be reported as additional to the 'base case'
2. physical data and prices need to be reported
3. costs need to be disaggregated as much as possible, but at least to the level of:
    - investment expenditure
        - installation costs
        - pollution control equipment
        - contingency allowance
    - operating and maintenance costs
        - energy costs
        - materials and services
        - labour costs
        - fixed operating and maintenance costs
        - subsequent costs
4. report revenues, avoided costs and benefits should be reported separately
5. taxes and subsidies should be reported separately
6. indirect costs should be reported separately
7. external costs should be excluded at this stage.

Where detailed cost data are not available to the same extent for all the options being compared, extra care will be needed in the final decision making so as not to be misguided as a result of missing data.

3.4 Guideline 8 – Process and present the cost information

Once the cost information has been gathered, it needs to be manipulated, so that the alternative options under consideration can be compared equitably. There is often a need to be able to handle issues such as the different operational lifetimes of the alternatives, interest rates, the cost of loan repayments, the effects of inflation, and exchange rates. The user also needs to be able to make comparisons between costs that may have been derived at different times. Some methodologies are set out below for manipulating and expressing the costs in such a way that fair comparisons can be made. The methodologies are again derived from the European Environment Agency's 'Guidelines for defining and documenting data on costs of possible protection measures' [6, European Environment Agency, 1999].

The most important issue when manipulating the costs is that the methodologies used and the steps involved are transparent. There is some flexibility, for instance, to apply different interest and exchange rates depending on the circumstances, but throughout this stage in the assessment, the user needs to justify the choices made and ensure transparency in all calculations used.

3.4.1 Exchange rates

Where prices have been quoted in different currencies, they often need to be converted to a common currency. When making this conversion, the user will need to specify the exchange rate used in the calculation, as well as the source and date of that exchange rate. An important source of European price indices and exchange rates is provided in Annex 10.

3.4.2 Inflation

The general price level and the relative prices of goods and services (e.g. environmental protection techniques) change with time because of inflation. Therefore, there needs to be a way of comparing different costs and benefits incurred or realised in different time periods. There also needs to be a way of comparing prices for alternative options, which may have been quoted in different years.

Inflation may also be a significant factor in the cost calculation from a constructor's perspective. The construction of a plant can take a number of years from the time capital is sanctioned, depending on the size and complexity of the plant. The cost of labour and materials can escalate during this construction period. The final cost of the plant will, therefore, be higher than if the plant had been constructed instantly when the expenditure was actually sanctioned. The theoretical cost of a plant procured and erected instantly is known as its 'index' or 'instant' cost. To estimate the final monetary 'completion' cost of a plant, knowledge of the expected timing of the capital phasing over the construction period, together with the expected rate of inflation of prices, is required. If the capital investment is phased, this can also be calculated as the present value in the current year (see Section 3.4.2.1).

The methodologies set out below allow the user to express prices that were quoted in one year in the equivalent price in the 'base year'. The difference between real and nominal prices is explained in Section 3.4.2.2. More information on the use of discounting and interest rates can be found in Section 3.4.3.

3.4.2.1 Establishing prices in the base year

The cost data that is available for different environmental protection techniques might relate to different years. For example, the capital equipment costs of one pollution control system may be valued at current prices in 1991, whereas the capital equipment costs of another system may be valued at current prices in 1995. Direct comparison of the two data sets would thus be misleading. Also, cost data for some environmental protection measures may only be available for years other than the base year of the study. For example, a reference may quote the cost of a piece of pollution control equipment as DEM 1.5 million in 1992, yet the base year of the study for which the data are required might be 1995. Assuming prices have risen over the intervening period, if the quoted cost is used directly in the study, the results will be an underestimate. Alternatively, if the base year for the study is 1990 and the quoted cost is used directly, the results will be an overestimate.

When making cost comparisons between pollution abatement measures, it is important to ensure that all raw cost data are expressed on an equivalent price basis, i.e. in the prices of a common year. Moreover, if the cost data are to serve as input into some form of economic analysis, it is advisable that this 'common' year corresponds to the 'base year' of the analysis.

A procedure for expressing the raw cost data in the prices of a selected year is given below. The procedure is expressed in terms of the 'base year' of a study, but it could just as easily refer to any year of interest.

To adjust the cost data into an equivalent price in a selected year, it is necessary to use a price adjuster, which can be derived by the following two steps:

Step 1:

$$\text{price adjuster} = \frac{\text{appropriate price index for the 'base year' of the analysis}}{\text{appropriate price index for the year to which the raw cost data pertains}}$$

Step 2:

$$\text{adjusted cost data} = \text{original cost data } x \text{ price adjuster}$$

An important source of European price indices is provided in Annex 10.

Where price adjustments have been made to express the cost data in a chosen year, then the index used to make these adjustments should be clearly stated.

3.4.2.2 Real and nominal prices

It is recommended that ‘real prices’ (sometimes called ‘constant prices’) are used in the assessment, these are prices that are recalculated to the given base year in order to take account of inflation. This is as opposed to ‘nominal prices’, which are the prices that would have been quoted at the time of the quotation, i.e. without any adjustment for inflation. Real prices can be estimated by deflating nominal values with a general price index, such as the implicit deflator for ‘Gross Domestic Product’ or the ‘Consumer Price Index’.

Some simple relationships for converting between ‘nominal’ and ‘real’ prices are provided below:

$$\text{real price} = \frac{\text{nominal price in a given year}}{\text{price deflator for that year } x \, 100}$$

$$\text{nominal price} = \text{real price in a given year } x \, \frac{\text{price deflator for that year}}{100}$$

$$\text{price deflator} = \frac{\text{nominal price series for a given year}}{\text{real price series in that year}} \, x \, 100$$

The price deflator used and how it was derived should be documented in the assessment. Again a useful source of European price indices is provided in Annex 10.

See the example below.

Example

Expressing the original cost data on an equivalent price basis in the base year.

[6, European Environment Agency, 1999]

Consider a pollution control system with annual energy savings of GBP 5620 (pounds sterling – UK currency) recorded at current prices in 1991, i.e. it saves 1 GWh of heavy fuel oil (HFO) per year at a price of GBP 0.00562 per kWh. Now suppose that it is necessary to express the cost data for this control system in 1995 prices - as 1995 is the base year for a cost study. The required adjustment is shown below.

Step 1:

$$\text{price adjuster} = \left(\frac{\text{current price index (of HFO) for UK industrial sector (1995)}}{\text{current price index (of HFO) for UK industrial sector (1991)}}\right)$$

$$= \left(\frac{114.2}{87.8}\right)$$

$$\text{price adjuster} = \underline{1.301}$$

Step 2:

$$\text{'nominal' price of HFO (1995)} = (\text{'nominal' price of HFO (1991)} \; x \text{ price adjuster})$$

$$= \text{GBP } 0.00562/\text{kWh} \;\; (1991) \;\; x \, 1.301$$

$$= \underline{\text{GBP } \; 0.00731/\text{kWh} \;\; (\text{in } 1995)}$$

The future real price in a given year is equal to the future nominal price divided by one plus the inflation rate that prevailed over the period under consideration. Therefore, using the seasonally adjusted GDP deflator at market prices to measure inflation between 1991 and 1995:

$$\text{'real' price of HFO in 1995} = \left(\frac{\text{'nominal' price of HFO in 1995}}{\text{change in UK GDP deflator from 1991 to 1995}}\right)$$

$$= \left(\frac{\text{GBP } 0.00731/\text{kWh}}{119.8/106.5}\right)$$

$$= \underline{\text{GBP } 0.00650/\text{kWh}}$$

The denominator in the above equation is equivalent to:

$$\left(\frac{\text{seasonally adjusted GDP deflator at market prices (1995)}}{\text{seasonally adjusted GDP deflator at market prices (1991)}}\right)$$

$$= \left(\frac{119.8}{106.5}\right) = \underline{1.125}$$

$$= 1 + \text{inflation rate between 1991 and 1995}$$

The nominal value of annual energy savings at current prices in 1995 are GBP 7310 (i.e. 1 GWh x GBP 0.00731/kWh). In real terms, the annual energy savings are GBP 6500 (i.e. 1 GWh x GBP 0.00650/kWh).

3.4.3 Discounting

3.4.3.1 Present value

Discounting is the mechanism whereby costs and benefits that accrue at different points in time are weighted so that they can be expressed in the same year and then compared. For example, the value of EUR 1 today will be different to the value of that same EUR 1 in one years time, due to inflation, prices changes, or simply because we would prefer to have that money today rather than in a years time. Discounting allows the user to compare preferences for spending that money either today or in the future. The value derived by discounting is called the 'present value'.

The 'present value' can be derived from the following formula:

$$\text{present value} = \frac{\text{cost}_n}{(1+r)^n}$$

Where:

Cost = the cost of the project over n years
n = the project lifetime (years)
r = the discount (interest) rate

For a series of costs that occur over a number of years the following formula can be used:

$$\text{present value} = \sum_{t=0}^{n}\left(\frac{\text{cost}_t}{(1+r)^t}\right)$$

Where:

Cost$_t$ = Cost in year t
t = year 0 to year ***n***
n = the project lifetime
r = the discount (interest) rate

3.4.3.2 Net present value

To evaluate and compare alternative investment options, the 'net present value' (NPV) method is used. This is the value of the investment calculated as a sum of discounted future payments minus the investment's current cost.

Net present value can be calculated from:

$$\text{NPV} = -(\text{investment expenditure}) + \sum_{t=0}^{n}\left(\frac{\text{net revenues}_t}{(1+r)^t}\right)$$

Where:

t = year 0 to year **n**
n = the project lifetime
r = the discount (interest) rate.

The NPV method takes into account 'the time value of money'. Cash payments and incomes are included regardless of the time when they were paid or received. However, the method is highly dependent on the discount rate used. For instance, a 1 % unit change in the discount rate may distort the results significantly.

This calculation is widely used to assess commercial investment options and normally requires a positive NPV to be achieved before an investment is sanctioned. However, when assessing environmental investments this rule cannot be applied, as these investments might well return a negative NPV. This is because the environmental benefits of the project are not sold on the market, so they cannot be included directly in the calculation. This problem is related to the question about shadow prices and external costs and explained in Chapter 4.

3.4.3.3 Discount and interest rates

The cost of capital is different for different investors, so interest rates will differ, depending on who is making the investment or providing the finance. Industry and commerce, agricultural investments, regional and local governments, central government and consumers all attract different interest rates. Different interest rates are also typically applied to account for different risks involved in projects, with a higher interest rate being applied to riskier investments. The user should select the most appropriate interest rate for the assessment but will have to justify the choice. Any assumptions about the interest rate should be clearly stated when presenting the results. Noting how using a different interest rate can significantly change the results, there is a strong interaction with assessing the economic viability of the sector, see Section 5.5.

It is also recommended that 'real interest rates' are used. This is an interest rate which has been adjusted to remove the effect of expected or actual inflation. The alternative is to use a 'nominal interest rate'. This is one which has not been adjusted to remove the effects of actual or expected inflation. Whichever type of interest rate is chosen, it should be clearly stated in the assessment and applied consistently throughout the analysis. Thus real interest rates are used in combination with real prices; nominal interest rates are used in combination with nominal prices.

The real interest rate can be calculated using the formula:

$$\text{real interest rate} = \left[\frac{(1 + \text{nominal interest rate})}{(1 + \text{inflation rate})}\right] - 1$$

The box below gives three examples of different discount rates that have been used in different reporting situations.

Three examples of different discount rates that have been used in different situations.

[6, European Environment Agency, 1999]

'A real discount rate of 6 per cent was used, as recommended by the Ministry of Finance. The rate may be described as both a rate of time preference and the cost of capital, based on the long-term, pre-tax cost of capital for low risk projects in the private sector.'

'A real pre-tax rate of 6.8 per cent was used, assuming that the nominal pre-tax return on lending is 10 per cent and the expected inflation rate is 3 per cent. This rate may be regarded as a private consumption rate of discount or the private time preference rate.'

'A real pre-tax interest rate of 7.43 per cent was used. This was obtained by adjusting the nominal rate of return (8.7 per cent) on the most recent Government issue of ten-year bonds, for expected inflation of 2.3 per cent per year. The return on Government bonds has been shown to display similar trends to the cost of interest bearing capital to industry. A margin of 1 percentage point (in real terms) has been added to reflect the average incremental risk associated with lending to industry, and the costs to the lender.'

When discount or interest rates are used, the following supplementary information needs to be provided:

- the discount or interest rate used should be clearly stated. It is recommended that a 'real interest rate' is used, i.e. one that has been adjusted for inflation. The basis of the rate should be explained as well as any underlying assumptions. If the rate is country, sector or company specific then this should be stated
- the source of the rate should also be referenced
- if any adjustments have been made to the referenced rate, for example, for variations in lender risk, then these adjustments should be explained and the reasoning behind them justified
- if interest rates are assumed to be variable, then this should be stated, along with the period to which each rate applies
- discount and interest rates should also be applied before any tax consideration, i.e. a pre-tax rate should be applied to pre-tax cost data.

3.4.4 Calculating annual costs

Cost data should preferably be calculated and presented as annual costs. In determining annual cost data, the approach that has been used to derive the annual costs should be recorded, along with all underlying assumptions. This is typically accomplished by converting all the cash flows accruing over the economic lifetime of a technique to an equivalent annual cost (sometimes the alternative terms: 'equivalent uniform annual cost', 'equivalent uniform annual net disbursements', 'annual worth-cost', or 'annualised cost' are used instead of annual costs).

There are two approaches for calculating the total annual cost of an investment, and the calculations for these are described below:

Approach 1

Total annual cost = the present value of the total cost stream (investment expenditure plus net operating and maintenance costs) x capital recovery factor, i.e.

$$\text{total annual cost} = \left[\sum_{t=0}^{n} \frac{(C_t + OC_t)}{(1+r)^t}\right]\left[\frac{r(1+r)^n}{(1+r)^n - 1}\right]$$

Where:

t=0 the base year for the assessment

C_t = total investment expenditure on the proposal in period t (typically one year)

OC_t = total net operating and maintenance cost on the proposal in period t

r = the discount (interest) rate per period

n = the estimated economic lifetime of the equipment in years

Net costs refer to the difference between additional gross costs associated with implementing a technique and the benefits, revenues, and avoided costs that will result. These net costs may be negative, if so then it is a profitable technique.

Equation 3.1: Approach 1 – Calculating the total annual cost of an investment

Approach 2

Total annual cost = annual capital cost (capital costs x capital recovery factor) + net annual operating and maintenance costs.

$$\text{total annual cost} = C_0\left[\frac{r(1+r)^n}{(1+r)^n - 1}\right] + OC$$

Where:

C_0 = the cost at year 0 (the base year)
r = the discount (interest) rate per period
n = the estimated economic lifetime of the equipment in years
OC = total net operating and maintenance cost (constant for every year)

Equation 3.2: Approach 2 – Calculating the total annual cost of an investment

The first approach, offers greater flexibility in that it provides a framework for explicitly accounting for the effects of real price rises of the various operating and maintenance cost components.

Clearly the total annual cost calculated can vary greatly according to the values used as input values in these equations. When reporting annual cost data, the approach that was used to derive the annual costs should be detailed, along with all underlying assumptions, including:

- the lifetime of the technique used in the calculation
- the time period required to install the abatement equipment
- the discount rate(s) used
- the relevant cost components, including all the assumptions made regarding the treatment of residual (salvage) value.

3.4.5 New plant location

At present, investment costs can generally be assumed to be similar for any EU country without correction for location. This may not be the case when data are collected from non-EU plants [29, CEFIC, 2001]. In practice, when comparing the cost of installed plants in different countries, coefficients are often used to take account of the differences. If this is undertaken, any assumptions made and how the coefficients were applied need to be stated clearly to ensure transparency.

3.4.6 Other ways to process cost data

Although it seems most appropriate to express cost data as annual costs for the assessment of industrial pollution control systems, there are other common and useful ways to express the data, such as:

- **the cost per unit of product**. This may be useful for assessing the affordability of the technique in comparison with the market price for the goods produced. The cost per unit can be calculated from the annual cost divided by the best estimate of the yearly average production rate during the period being considered
- **the cost per unit of pollutant reduced or avoided**. This may be useful as a basis for analysing the cost-effectiveness of the technique (see Section 4.1).

3.4.7 Summary of Guideline 8

The following points are a summary of how the cost information should be processed and presented:

- express the original cost data in the price level of a common year
- the discount or interest rate used should be clearly stated
- the 'real discount rate' and 'real prices' should be used
- the basis of the rate used should be explained, as well as any underlying assumptions made. If the actual rate used is country, sector or company specific then this should be stated and the source of the rate should be referenced
- discount and interest rates should be applied before any tax consideration
- cost data are preferably calculated and presented as annual costs.

3.5 Guideline 9 – Attributing costs to environmental protection

Reported cost data should distinguish between those resources consumed by techniques that are implemented purely for the purpose of reducing or preventing emissions of pollutants, and those techniques that may be implemented for other reasons. These other reasons might include investment expenditure in energy conservation or waste minimisation technologies, which can yield commercial benefits that offset their costs. In some cases it can be useful to differentiate between those costs that are offset by commercial benefits and those that can be attributed to environmental protection.

In general, end-of-pipe techniques tend to serve no other purpose than to reduce or prevent pollutant emissions. The entire investment expenditure for an end-of-pipe technique, including operating and maintenance costs can be regarded as environmental costs and can be attributed to environmental protection.

In contrast, difficulties arise when assessing the environmental costs of process-integrated measures, as these affect the entire production process, and may serve other purposes in addition to pollution abatement. In this case, the entire resource cost cannot be attributed solely to environmental protection, as there are other benefits such as productivity improvements, or improved product quality. Where these benefits lead to savings that are greater than the cost of the environmental component, then the payback time of the measure should first be considered. If the payback time is less than three years, then the project is economically attractive to the operator and thus could be assumed, for the purposes of attributing costs, not to be primarily driven by environmental considerations [6, European Environment Agency, 1999]. In this case, there is no need to evaluate it further using this guideline.

In cases where the payback time is longer, the costs of the proposed project can be compared with those of similar projects in which no allowance is made for the environmental aspect. The difference between the two amounts can be regarded as the environmental component. This complicates the assessment and if clear comparisons are not possible, then the judgement will have to be made based on the limited information available.

Once a technique has been established, it may well become the standard and less environmentally benign alternatives might cease to be available. When such a situation occurs, the technique is no longer considered to incur environmental costs [6, European Environment Agency, 1999].

Although attributing costs to environmental protection might not always be straightforward, it is essential that the reasons and justifications used to attribute the costs are transparent. The user should ensure that any decisions or assumptions made at this point are clearly stated in the assessment.

4 EVALUATING THE ALTERNATIVES

After the environmental effects and the economic costs have been estimated for each of the alternative techniques, the alternatives need to be compared to determine which, if any, meet the criteria of BAT. As said elsewhere in this document, the ultimate decision will rest with expert judgement which can be assisted by the approaches described below. The cost effectiveness of a technique is crucial to the determination of BAT and, in this respect, it is useful to find out which technique offers the most value (environmental benefits) for money (costs). This section discusses ways of determining cost effectiveness of each option and how some benchmarks or reference points relating to environmental benefits could be used to assist the determination of BAT. Evaluating the alternatives in this way can assist transparency and consistency by setting out the reasoning behind the decision.

The way that the previous chapters on cross-media effects and the costing methodology fit together with the methodologies discussed in this chapter are shown schematically in Figure 4.1 below.

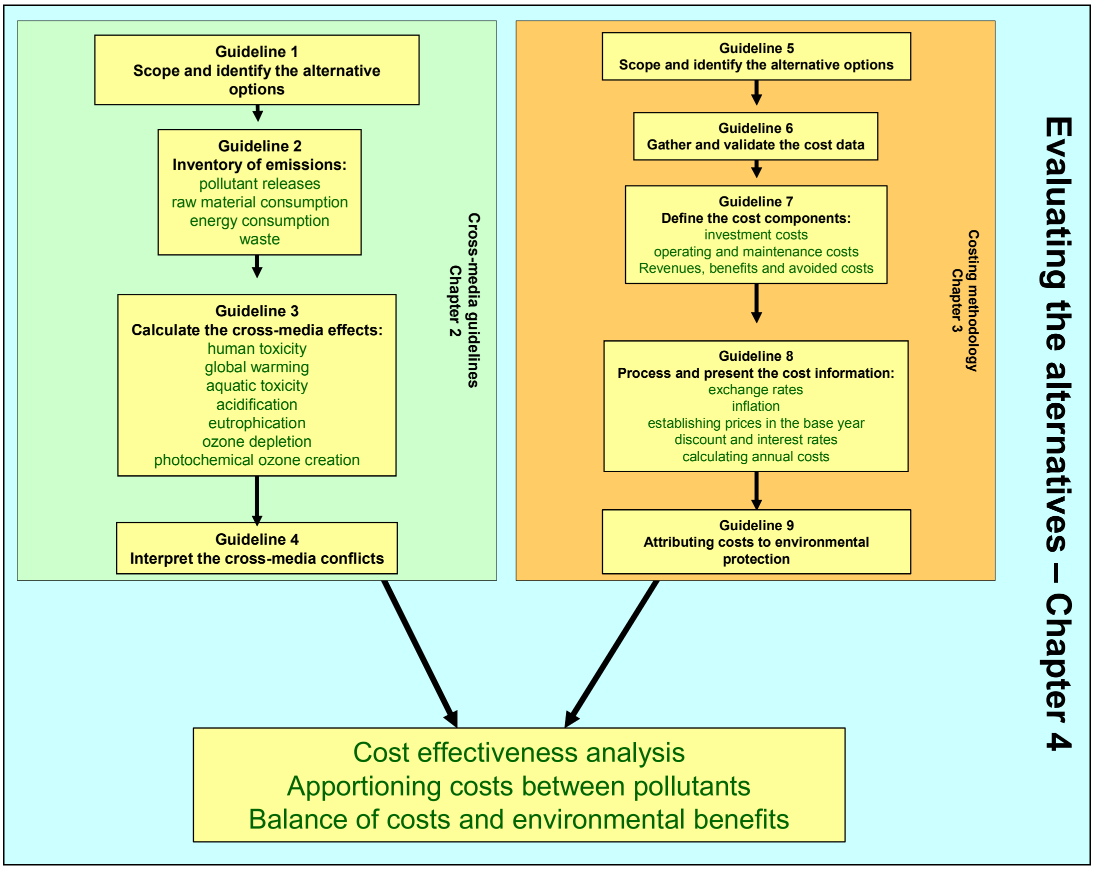

Figure 4.1: Chapter 4 Evaluating the alternatives

4.1 Cost effectiveness analysis

Cost effectiveness analysis is a well-known technique, frequently used in the preparation or implementation of environmental policy. The basic concept is simple: one can spend a euro only once. In the context of environmental policy this means that the aim is to achieve highest environmental yield for each euro invested for environmental purposes.

The most explicit way to compare costs and benefits of a measure is to monetarise both and compare them in a cost benefit analysis (CBA). When the comparison shows that the benefits outweigh the costs, this indicates that the measure represents a worthwhile investment. If different alternative measures give positive results, the measure with the highest result is the one offering the highest overall value for money. However, such a cost benefit analysis requires a lot of data and some benefits are difficult to monetarise.

A cost effectiveness analysis is more simplified than a CBA as environmental benefits are quantified but not monetarised. This type of analysis is typically used to determine which measures are preferable to reach a specific environmental target at the lowest cost.

Cost effectiveness (CE) of a technique typically is defined as:
[61, Vito, et al., 2003]

$$\text{CE} = \frac{\text{annual cost}}{\text{annual reduction of emissions}} \quad \text{(e.g. 5 EUR/kg VOC reduced)}$$

In the context of determination of BAT, the use of the CE concept is not straightforward. However, ranking BAT options on the basis of ascending CE is useful, e.g. to exclude options that are unreasonably expensive in comparison with the environmental benefit obtained. Suggestions on how to deal with this issue are presented later in Section 4.3

4.2 Apportioning costs between pollutants

The methodology to determine the cost of BAT options has been dealt with in the previous chapter. In this paragraph, some additional information is provided on how to apportion costs between the pollutants that will be abated.

In most cases, the primary environmental effect can be represented by a single number (e.g. just NO_X reduction, just CO_2 reduction, just the summed local effects to air or just the summed local effects to water). Where there are a range of pollutants that will be abated by the implementation of a technique, there needs to be a way of apportioning the costs between the different pollutants that are abated. For example, catalytic converters reduce the emissions of NO_X, VOCs and CO. Therefore, this measure will not only reduce photochemical ozone creation effects (the primary reason for their introduction), but might also deliver reductions in eutrophication and acidification.

If the costs associated with an environmental protection technique have been apportioned between pollutants, the method of apportionment should be described.

There are two possible approaches to apportioning the costs:

(1) The costs of the technique can be attributed in full to the pollution problem for which the measure was originally intended. For the catalytic converter this would be the photochemical ozone creation effects of air pollutants. The effects on other pollutants are then seen as an additional benefit, free of any costs.
(2) An apportionment scheme can be devised for distributing the costs between the environmental effects concerned.

When evaluating IPPC techniques, the first approach described above (i.e. (1)) is more useful as it is more transparent. If the second approach is used, the methodology should be set out clearly when reporting the results, ensuring that the methodology for distributing the costs is transparent and fully explained in the final report.

4.3 Balancing costs and environmental benefits

In the determination of BAT it is necessary to balance costs and benefits, or, in other words, to find techniques that are reasonably cost effective. This section presents some methodologies on how to assess what cost effectiveness is still reasonable and what is not.

4.3.1 Reference prices

'Reference prices' are values that have been used to help the decision-making process in various Member States. The terminology used, as well as the methodologies used for deriving the values vary, but again they can be a useful tool for determining whether or not investing in a certain technique represents value for money. The terms used for the values that are derived for the polluting effects include 'shadow prices', 'reference costs', 'benchmark prices' and 'levies'. Once the user has a value that can be attributed to an environmental effect, then this value can be used in the same way as described in Figure 4.3 below. Some examples of how 'shadow prices' are derived and used in certain Member States are discussed below.

Denmark

Values for the environmental effects of pollutants were used in the report: 'En omkostningseffektiv opfyldelse af Danmarks reduktionsforpligtelse' (A cost effective fulfilment of the Danish reduction commitment) 2003, where several measures for reducing CO_2 are analysed and the costs of these measures are estimated. [50, Bjerrum, 2003].

In these reports, there was some discussion on the fact that CO_2 reducing measures also reduce the emissions of SO_2 and NO_X and, therefore, these are considered positive side effects. Two different valuation techniques (abatement costs and damage costs) are used to derive a value for the effect of the pollutants:

(1) The reduction of NO_X and SO_2 takes place on a power plant with the aim of achieving NO_X and SO_2 quotas (that are not transferable). The economic values of NO_X and SO_2 reflect the operators' alternative costs of fulfilling the quotas, (i.e. the marginal costs of reducing the emissions in another way). For SO_2, the marginal costs are valued as equal to the tax on SO_2, introduced in 2000 at a rate of DKK 10/kg SO_2. For NO_X, the marginal costs are estimated to be DKK 14.5/kg. This value is based on the costs of installing a deNO_X system on a coal fired power plant.

(2) The costs are taken from ExternE, and are set at DKK 30/kg for SO_2 and DKK 35/kg for NO_X. It was accepted that these costs are subject to substantial uncertainty.

United Kingdom

The Environment Agency for England and Wales is currently deriving 'benchmark costs' based on the cost of investments in similar technology that have already been made. The Agency is compiling a database of the costs of abatement technologies as they are installed. They envisage that the information in this database will help to ensure that there is better consistency between the investments expected in different industrial sectors. These costs are indicative of the historic level of expenditure to control a certain pollutant and can be used as guide values to determine whether future investment costs could be reasonable.

Sweden

An illustration of how reference values have been used in Sweden is set out below [58, Ahmadzai, 2003]:

Often an environmental protection measure results in the abatement of pollutants impacting on several media. The calculation of the 'abatement cost' can be illustrated by the following two examples:

1) Assume an annual cost of EUR 1 million (1000000) for reducing NO_X emissions by 200 tonnes/year, (i.e. at a cost of EUR 5/kg (approximately EUR 1/kg more than the levy of EUR 4/kg - the levy is charged to encourage reductions in various pollutants and redistributed back to industry). Additionally, it is assumed that in this case odour is also substantially abated.

   A technique costing up to EUR 4/kg NO_X normally appears attractive as it avoids the levy costs. The difference between the actual cost and the cost that would normally be attractive is considered against any other benefits. In this case a reduction of 200 tonnes NO_X per year at EUR 4/kg equates to a reduction of EUR 800000 in the levy. If it can be argued that odour reduction at a cost of EUR 200000 per year (i.e. EUR 1000000 - EUR 800000) is desirable, then the investment as a whole can be justified.

2) Assume that for an annual cost of EUR 1.2 million, NO_X is abated by 250 tonnes/year and also that, at the same time, sulphur is reduced by 100 tonnes/year. With the levy for NO_X at EUR 4/kg and the tax for sulphur at EUR 3/kg, the assessment would then be as follows:

Annual cost for investment and operation = EUR 1200000
Value of 100 tonnes sulphur at EUR 3/kg = EUR 300000
Balance attributed to NO_X reduction = EUR 900000
Unit abatement cost for NO_X (900000/250000) = EUR 3.6/kg (this is below the EUR 4/kg levy) and the investment represents value for money.

Conclusion: The abatement of other pollutants into various media can be taken into account with respect to shadow prices (levies) and assessed in light of the accumulative advantage offered by an investment.

REF: Swedish EPA Report 4705 Beräkningar av kostnader för miljöskyddsinvesteringar; 1996/03

There are also values used for planning purposes in Sweden. The following key values for various pollutants are recommended in SIKA Report 2000:3 'ASEK Kalkylvärden i Sammanfattning', April 2000 and are presented with actual values used in levies and taxes in Sweden. [51, Ahmadzai, 2003]:

Estimation of air pollutants, SEK/kg (1999 prices for regional impacts):
NO_X = SEK 60/kg (actual levy of SEK 40/kg which is redistributed to industry)
SO_2 = SEK 20/kg (actual tax levied SEK 15/kg SO_2 or SEK 30/kg S)
VOC = SEK 30/kg (no tax or levy applied but SEK 50 – 100/kg VOC considered "bearable" for various industrial sectors/applications)
CO_2 = SEK 1.5/kg
A discount interest rate (real) of 4 % is recommended.

The example below provides an illustration of how a choice of technology, taking into account cross-media effects, can be facilitated using the Swedish approach. The investment cost is for a certain capacity of an industrial operation. Annualising the cost takes into account a capital recovery factor.

Table 4.1 presents the unit emissions or consumptions from two technology options that offer equivalent post-project production capacities in tonnage but differ in volumetric capacities. Table 4.2 compares these options using shadow prices and levies that are typical for Sweden. Table 4.3 depicts the annual benefit that can accrue from the options and relates them to annualised investment cost of the two options and also summarises the benefit/investment ratio that helps provide a decision tool to assess the alternatives. The issues that require motivation during the permitting exercise are essentially those that need prioritisation at the local decision level. These tend mainly to cover:

- the valid or arguable shadow price taken into consideration
- pollutants that are deemed to have priority for a particular application
- the relevant economic recovery factor (considered to be reasonable with respect to operator, the negotiating and the permit issuing authorities)
- an appropriate combination of above.

Units per year	**Pre-project**	**Option 1**	**Option 2**
Production, m^3	625000	1500000	1250000
Production, t	56000	59000	59000
Environmental parameters			
SO_2	250	168	82
NO_X	30	30	10
CO_2	24000	700	23000
Dust	380	100	280
Phenol	27	25	2
Ammonia	52	34	18
Formaldehyde	15	15	0
VOC	94	74	20
BOD	100	10	15
P_{tot}	20	2	10
N_{tot}	50	5	20
Water	23000	23000	10000
Waste	100000	34000	30000
Energy in MWh/yr	44210	40000	44210

Table 4.1: Emission and consumption data for two technology options 1 and 2

	Shadow cost EUR/unit	**Unit reduction per year Option 1**	**Shadow cost EUR/yr equivalent**	**Unit reduction per year Option 2**	**Shadow cost EUR/yr equivalent**
SO_2	1500	82	123000	168	252000
NO_X	4000	0	0	20	80000
CO_2	150	23300	3495000	1000	150000
Dust	10	280	2800	100	1000
Phenol	see VOC	2		25	
Ammonia	see VOC	18		34	
Formaldehyde	see VOC	0		15	
VOC	5000	20	100000	74	370000
BOD	810	90	72900	85	68850
P_{tot}	23000	18	414000	10	230000
N_{tot}	11000	45	495000	30	330000
Water	1		0	13000	13000
Waste	100	66000	6600000	70000	7000000
Energy, MWh/yr	2	4210	8420	0	0
Total of all Media Cost 'Benefits', EUR/yr			**11311120**		**8494850**

Table 4.2: Comparison of technology options 1 and 2 using shadow costs

Indicator		Option 1	Option 2
Total all-media 'benefits', EUR/yr		**11311120**	**8494850**
INVESTMENT (EUR)		30023000	31000000
Capital recovery factor, 10 %, 10 yr	0.16275		
Annualised investment (EUR/yr)		4886243	5045250
Benefit/investment ratio		**2.31**	**1.68**

Table 4.3: Comparison of costs and 'benefits'

Conclusion: In the above case, option 1 offers a better balance of costs and benefits as shown by a higher benefit ratio of 2.31 vs 1.68.

Belgium

Dutch 'indicative reference values' (the term used for shadow prices) have been used to determine a cost effectiveness range for VOCs, particulates, NO_X and SO_2 [53, Vercaemst, 2003]. The range is based on a sample of reduction measures that were implemented in practical cases in the Netherlands. It shows which levels of cost effectiveness were acceptable at the time that they were implemented. This methodology was used to determine what level of cost effectiveness is still 'reasonable'. For this purpose, it was clear that only the highest value of the sampled cost effectiveness range is critical and the 'indicative reference values' are therefore, based on these highest values. They were derived by excluding measures that were implemented for highly specific purposes.

The approach indicates which measures are more cost effective than the 'indicative reference values' and are therefore, in theory, acceptable and reasonable. Measures or techniques that are less cost effective than the indicative reference values are considered to be, in theory, unacceptable and not reasonable. The reference values have to be considered as 'theoretical' and 'indicative', as they can only provide an indication of what is reasonable and what is not; they cannot be used in all circumstances as hard and fast cut-off points. There needs to be some flexibility in their application for specific cases.

Reference values for total cost effectiveness

Component	Indicative reference value (EUR/kg emission reduction)
VOC	5[a]
Particulates	2.5[b]
NO_X	5
SO_2	2.5

[a] Excluding integrated measures, and cases where harmful VOCs such as benzene are emitted.
[b] Excluding the abatement of specific components of particulate matter, such as heavy metals, that can justify significantly lower values for the acceptable cost effectiveness.

Table 4.4: Indicative reference values for total cost effectiveness

Detailed background information on how these values were derived can be found in the InfoMil-document [54, Infomil, 2001].

Reference values for marginal cost effectiveness

It might be necessary to also consider marginal cost effectiveness of a technique. The marginal effect is defined here as the difference between the effect of the replacement or improvement of the existing measure and that of the existing measure. Marginal cost effectiveness is then defined as the quotient of marginal cost and marginal effect. The table below lists the lower and upper limit reference values for marginal cost effectiveness. These limits are set respectively at 1.5 times the indicative reference value of Table 4.4, and 4 times the indicative reference value.

In a new installation, usually, the only criterion is the total cost effectiveness. In an existing installation where existing environmental measures are improved or renewed, it is necessary to evaluate both the total and the marginal cost effectiveness.

Component	Lower limit for marginal cost effectiveness (EUR/kg emission reduction)	Upper limit for marginal cost effectiveness (EUR/kg emission reduction)
VOC	7.5	20
Particulates	3.75	10
NO_X	7.5	20
SO_2	3.75	10

Table 4.5: Indicative reference values for marginal cost effectiveness

The decision making process

Figure 4.2 illustrates how the reference values for both total and marginal costs effectiveness can be used.

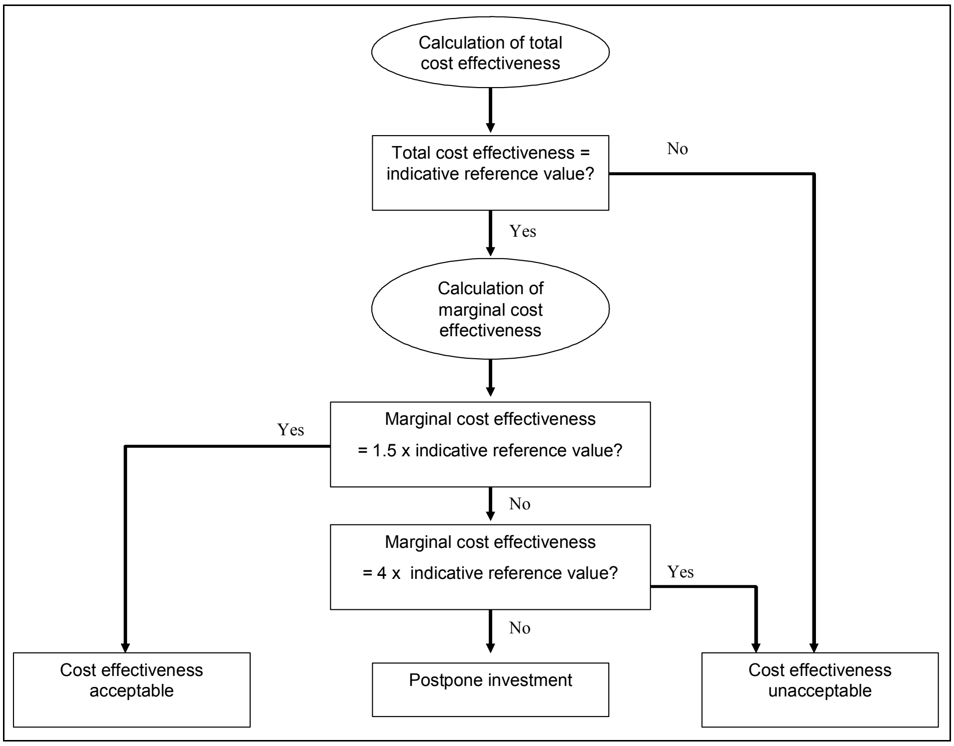

Figure 4.2: Decision making process for evaluating cost effectiveness

Use of reference values in the determination of BAT in Flanders

Since 1995, the Flemish authorities have commissioned Vito to determine BAT at the sector level. As of 2004, Vito's BAT-centre has published BAT reports on 30, mainly non-IPPC, sectors. For each sector, a stepwise procedure is followed to determine BAT. One of these steps is the evaluation of the economic availability of the alternative options under consideration. Vito considers that an option can only be determined to be economically acceptable if: (i) it is feasible for an average, well-managed company of the sector to implement the technique and (ii) if the cost effectiveness ratio is reasonable. Only in those cases where the economic acceptability is questionable is a detailed analysis carried out. The combustion plant sector was one of those activities where this economic analysis was necessary. This example is derived from the report 'Beste beschikbare technieken voor stookinstallaties en stationaire motoren" ('Best available techniques for combustion installations and stationary engines'). [52, Gooverts, et al., 2002]

This report evaluates industrial furnaces with a capacity of 100 kWth or greater, as well as stationary engines (gas engines, diesel engines, gas turbines) with a minimal output of 10 kW. The focus is on techniques to reduce NO_X and SO_2 emissions. For the alternative options that were considered, the total annual costs (investment and operational costs) were established as well as the reduction efficiencies. For the cost effectiveness evaluation, the Dutch reference values for total cost effectiveness Table 4.4 were used.

For example:

• pollutant	NOX
• installation	coal,>600 MW
• technique	low-NOX burner
• cost-effectiveness	EUR 1.3/kg NOX reduced.

Test: EUR 1.3/kg <EUR 5/kg; therefore the cost effectiveness of this technique is considered to be reasonable (+). The table below lists the outcome of the analysis carried out for Flanders.

Technique	Installation with coal for thermal capacity larger than (MW)					Installation with liquid fuel for thermic capacity larger than (MW)					Installation with natural gas for thermic capacity larger than (MW)				
	10	**50**	**100**	**300**	**600**	**10**	**50**	**100**	**300**	**600**	**10**	**50**	**100**	**300**	**600**
NO_X															
Flue-gas recirculation						+	+	+	+	+	+	+	+	+	+
Overfire air + flue-gas recirculation						+	+	+	+	+					
$LowNO_X$ burner	+	+	+	+	+	-	-	+	+	+	-	-	+	+	+
$LowNO_X$ burner + overfire air	-	+	+	+	+	-	-	+	+	+					
Reburning	+	+	+	+	+										
SNCR	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+
$LowNO_X$ + flue-gas recirculation						-	+	+	+	+					
Reburning + $lowNO_X$ burner						-	+	+	+	+					
$LowNO_X$ burner + SNCR											-	-	+	+	+
$LowNO_X$ burner + overfire air + SNCR	-	+	+	+	+	-	+	+	+	+					
$LowNO_X$ + flue-gas recirculation + SNCR						-	+	+	+	+					
SCR	-	-	+	+	+	-	-	-	+	+	-	-	-	+	+
$LowNO_X$ burner + SCR	-	-	+	+	+										
$LowNO_X$ burner + overfire air + SCR	-	-	+	+	+										
SO_2															
Dry adsorbens injection	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
Semi-wet (or dry spray tower)	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
Wet ammonia scrubbing	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
Wet scrubber lime(stone)	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
Wet scrubber dual alkali	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
Regenerative Wellman Lord	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
Combined NO_X/SO_2 techniques															
Activated carbon	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-
Alkali injection	+	+	+	+	+	-	+	+	+	+	-	-	-	-	-
$deSONO_X$-WSA-SNO_X	-	+	+	+	+	-	-	-	+	+	-	-	-	-	-
Low sulphur fuel	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
+ : reasonable cost effectiveness **- : unreasonable cost effectiveness**															

Table 4.6: Evaluation of cost effectiveness for NO_X and SO_2 reduction techniques for combustion plants in Flanders using indicative reference values.

4.3.2 External costs

Another way to assess whether a measure is cost effective is to compare the costs of the measure against the social cost of the damage to the environment that is avoided by implementing the measure. To be able to make this comparison, there has to be a mechanism for attributing an economic value to the pollution that would be avoided. Various methodologies have been developed to derive economic values for the effects of pollution.

The European Commission (DG Environment) derived external costs for some air pollutants. As part of the development of cost benefit analysis in the clean air for Europe (CAFE) programme[6], a special report was prepared[7] to provide a simple ready-reckoner for the estimation of the external costs of air pollution. External costs have only been derived for a few air pollutants and have not been derived for other environmental media[8].

The methodologies used to derive the values followed the basic methodologies developed by the ExternE[9] project but the methodology agreed for impact assessment and valuation in the CAFE-CBA analysis means that the methods used to quantify impacts and perform valuation have been subject to more intensive scrutiny and peer review[10] than was previously the case.

The modelling work that was carried out to derive these figures suggests that the results generated quantify a large fraction of total damages for most of the pollutants considered although some effects are omitted which are undeniably important. The pollutant for which the most serious omissions apply is probably VOCs, because of the failure to account for organic aerosols, and, possibly, a failure to account for impacts associated with long-term (chronic) exposure to ozone should they exist.

The effect of omission of impacts has to be seen in the context of the full range of uncertainties in the assessment including model assumptions and statistical uncertainties which may push the results either way, up or down. It is important to underline that the external costs in the CAFE CBA relate only to human health. Ecosystem externalities could not be monetised due to lack of data[11].

Derivation of these values is a complex process and involves a detailed analysis of the predicted impacts of the release of these pollutants. Methods for calculating the values follow the ‘impact pathway approach’, which involves tracing emissions through dispersion and environmental chemistry, to their impact on sensitive receptors (calculated using exposure-response functions). The values presented in Annex 12 of this document are taken from the CAFE CBA report dated March 2005. They are subject to future review and update.

There are many assumptions that have been made within these analyses, both when establishing the predicted environmental effects and when deriving values for these predicted effects, so users need to be aware of the considerable uncertainties that surround the derived values and use these numbers with caution. For application by policy makers, it is recommended that ranges are used and sensitivities explored, because of extensive uncertainties that affect external costs

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[6] See http://europa.eu.int/comm/environment/air/cafe/activities/cba.htm

[7] Service Contract for Carrying out cost-benefit analysis of air quality related issues, in particular in the clean air for Europe (CAFE) programme – Damages per tonne emissions of $PM_{2.5}$, NH_3, SO_2, NO_x and VOC from each EU25 Member State (excluding Cyprus) and surrounding seas. March 2005, AEA Technology Environment.

[8] See also http://europa.eu.int/comm/environment/air/cafe/ and http://www.cafe-cba.org/

[9] More information on the ExternE Project can be found at http://externe.jrc.es/

[10] Krupnick et al (2004), Peer review of the methodology of cost-benefit analysis of the clean air for Europe programme. Paper prepared for European Commission October 2004: http://europa.eu.int/comm/environment/air/cafe/activities/krupnick.pdf.

[11] Service Contract for Carrying out cost-benefit analysis of air quality related issues, in particular in the clean air for Europe (CAFE) programme – Methodology for the cost-benefit analysis for CAFE: Volume 3: Uncertainty in the CAFE CBA: Methods in the first analysis. April 2005, AEA Technology Environment

analysis. Bearing these uncertainties in mind, these benchmarks can still be a useful guide when discussing whether implementing a technique represents value for money.

Although the data are limited to NH_3, NO_X, $PM_{2.5}$, SO_2, and VOCs information provides a useful starting point for discussions.

The figure below shows how the figures can be used as a reference to compare the cost effectiveness of implementing various measures.

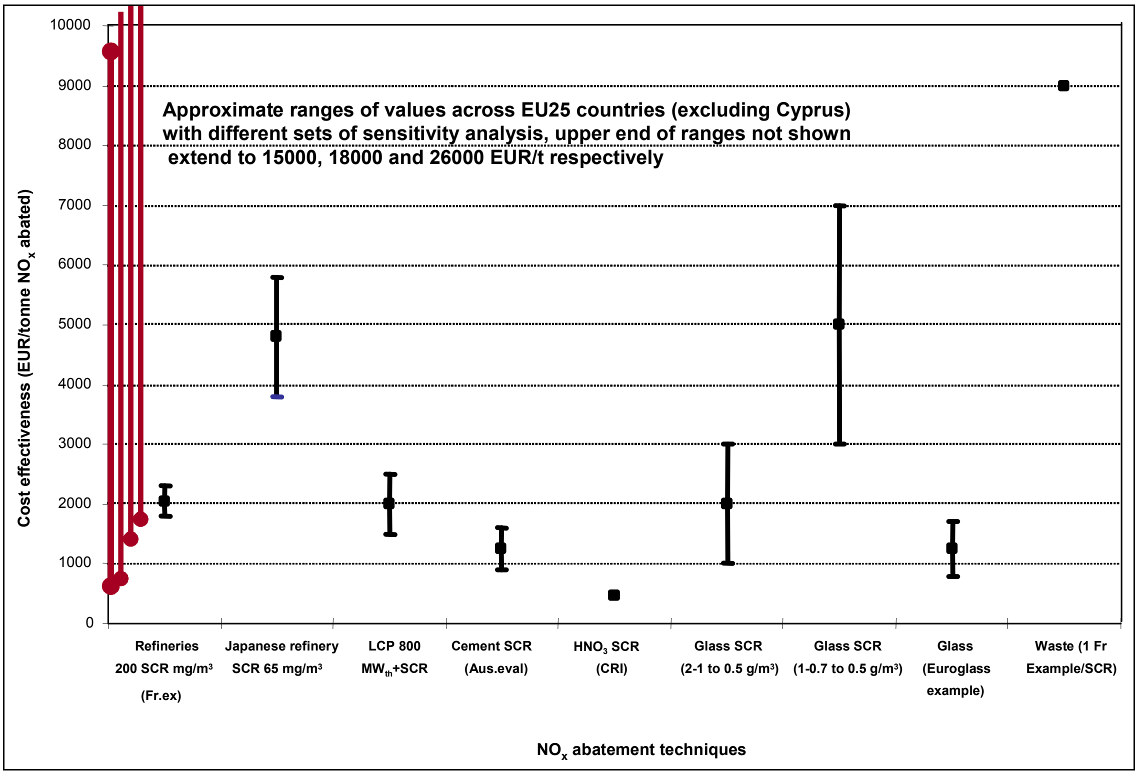

Figure 4.3: Cost effectiveness data for some NO_X abatement techniques

The data used in this figure are for illustrative purposes only (they cover a range of different sectors and these would not necessarily be compared against each other). The data is derived from information that was gathered for development of the ‘Mineral Oil and Gas Refineries BREF’ [23, EIPPCB, 2001] and is based on costs from the NO_xCONF conference 2001[12]; the methodology for calculating the costs pre-dates, and therefore has not been validated against, the costing methodology described in this document. The data does, however, provide a useful illustration as to how cost data and external prices can be compared. This allows the user to assess whether the environmental benefit delivered by implementation of the technique represents value for money. Evaluating the options in this way can be useful when developing the justification for the choice of the preferred technique.

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[12] NOXCONF Conference 2001 (International Conference on Industrial Atmospheric Pollution – NO_x and N_2O emission control). http://www.infomil.nl/legsys/noxconf/index.html

4.3.3 Conclusion on evaluating the alternatives

Ranking the alternatives by their cost effectiveness can be a useful way of identifying the best balance between the cost of a technique and the environmental benefits that implementing it will deliver. Some issues to consider when ranking the alternatives are discussed above but the user will need to decide which method is most appropriate. Evaluating the cost effectiveness of the alternatives under consideration can be useful in that it provides a structured way of determining the preferred technique and for setting out the justification for choosing that technique.

The cross-media guidelines in Chapter 2 allow the user to establish the critical environmental issues and, therefore, set the environmental priorities. The costing methodology in Chapter 3 allows the user to determine the costs of the techniques and to compare the cost of the alternatives in an even-handed way. Chapter 4 – Evaluating the alternatives, looks at ways of integrating environmental effects with the costs. Evaluation of the cost effectiveness of the techniques and also the value of the environmental benefit that implementing the technique will deliver can be useful in developing the justification for the decision.

The evaluation of cost effectiveness is fairly straightforward and very useful when there are several techniques under consideration. If there are external costs available, then these can be used as a useful guide in the decision-making process. There are several different benchmarks for cost effectiveness including external costs and shadow prices. Although there may be considerable uncertainties in the values that have been derived, they can be very useful in evaluating the benefits of implementing a technique and in the deliberations as to whether implementation of the technique represents value for money. This methodology is, of course, limited to a small number of pollutants for which the values have been derived.

The assessment of the trade-offs that have to be made between environmental effects and the costs of the alternative techniques can be complex. It is not possible to anticipate all of the possible eventualities in a methodology such as this, and where there are weaknesses these have been pointed out in the text. Although there is likely to be a need for some professional judgement when identifying the option that represents the best alternative, the methodologies discussed in this chapter should help the user make an objective judgement as to how to balance costs and benefits. The methodologies also allow for the justification to be set out clearly and help to establish a transparent audit trail for any decisions that are taken.

5 ECONOMIC VIABILITY IN THE SECTOR

5.1 Introduction

Within the definition of BAT in the Directive, there is a requirement that techniques that are determined to be BAT are those developed on a scale which allows implementation in the relevant industrial sector under economically and technically viable conditions (see the definition of ‘available’ from the Directive below). Determining whether implementing BAT in a sector is ‘economically viable’ (whether it is one technique or a combination of techniques that are to be implemented) is difficult because of the diversity of industrial sectors covered by the Directive. This chapter can assist by providing a framework to structure the debate when trying to determine whether the implementation of a technique is ‘economically viable in the sector’.

Directive definition of ‘available’ in Best Available Techniques:

‘available’ techniques shall mean those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator,

An assessment of economic viability is a part of determining BAT in a general sense at sector (BREF) level; the Directive makes no provision for such an assessment when determining permit conditions for an individual installation. An in-depth analysis will only be necessary when the techniques proposed will introduce a fundamental change in the industrial sector, and/or if the proposals are contentious.

The burden of proof to establish that the technique is not economically viable rests with the party raising the concern (usually industry) as they should have reasons for objecting and the necessary evidence, or access to it, to substantiate their objections.

The issues discussed below set out a framework which allows the economic viability assessment to be undertaken and the evidence to be set out. Once the assessment has been completed, it can be considered by the relevant Technical Working Group to decide whether or not, or even how, these issues affect the determination of BAT.

Expert judgement has played a large role in the evaluation of economic viability within the BREF process. Some Member States have experience of using more structured methodologies and some of these are included in this document. The four factors identified below are thought to be the most significant issues to consider in the assessment of ‘economic viability in the sector’:

- **industry structure**
- **market structure**
- **resilience**
- **speed of implementation**

The way these issues fit together in this assessment is shown diagrammatically in Figure 5.1 below. The decision as to whether the proposed investments are viable depends on the capacity that the sector has to absorb the extra cost, or to transfer these costs on to the customer or suppliers. The ability of the sector to pass the costs on depends on the ‘industry structure’ and ‘market structure’, whereas the ability of the sector to absorb the costs depends on the ‘resilience’ of the sector. If, after considering these issues, the package of BAT options is determined to be viable, there may be a need to consider a time-scale for the implementation of the techniques to ease their introduction in the sector, i.e. the ‘speed of implementation’.

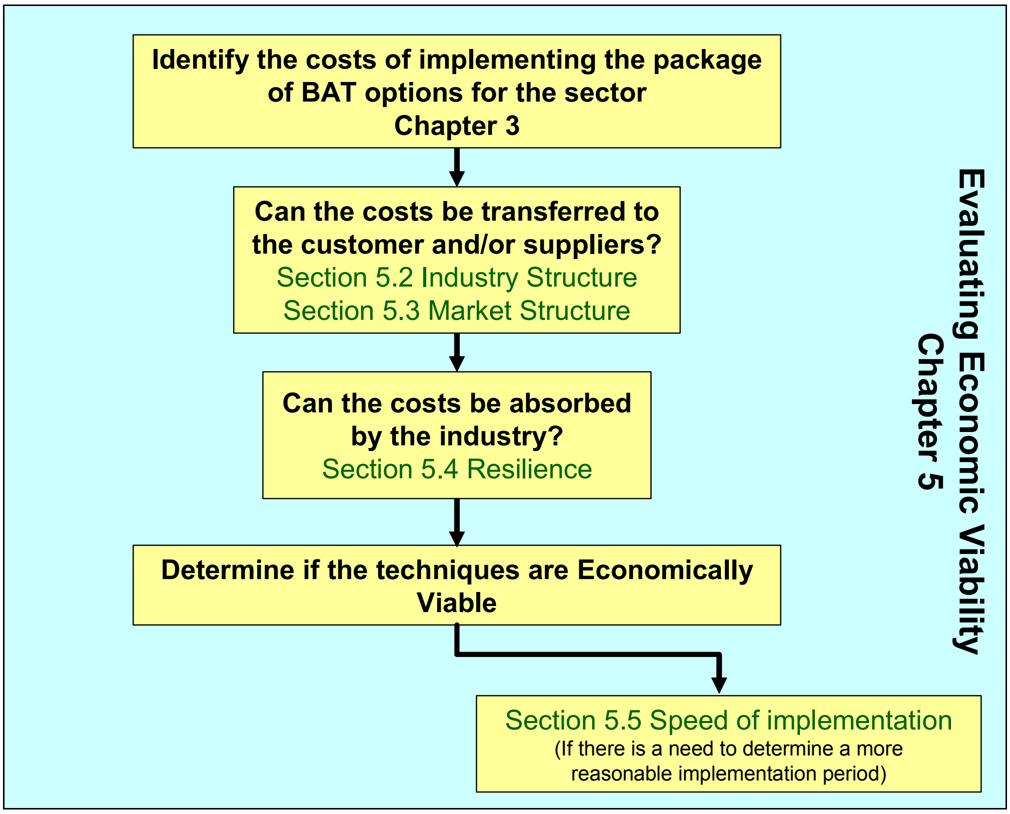

Figure 5.1: Evaluating economic viability for the sector

Each of the four factors is discussed in more detail below. Although there will inevitably be other issues that might be important for some sectors, narrowing the debate to these four key factors should improve the objectivity of the decision making process and help ensure that all sectors can be treated consistently.

The assessment will, in many cases, be a judgement-based process and as is often the case, comprehensive data may not be available, or may be subject to large uncertainties. These limitations will need to be understood from the outset when assessing economic viability and clearly stated in the report to ensure transparency.

5.2 Industry structure

'Industry structure' describes the socio-economic characteristics of the sector under consideration and the technical characteristics of installations in the sector. These characteristics give some insight into the structure of the industry and the ease with which new BAT techniques can be implemented.

5.2.1 Describing industry structure

Consideration of the following issues is useful when trying to describe the industry structure:

Size and number of plants in the sector - In some sectors such as 'iron and steel' and 'refineries', large scale integrated plants are typical, while in other sectors such as 'intensive livestock', much smaller plants are the norm. Alternatively, the sector might be characterised by a mixture of large and small plants, as is the case in the 'textiles' and in the 'pulp and paper' sectors.

Different sized plants can react differently to the implementation of BAT - larger plants can deliver economies of scale, but capital costs for equipment will generally be high and there are usually long lead times for the replacement of equipment. Replacements for smaller sized plants and equipment may be less capital intensive, but payback times for equipment may be just as long as those of larger plants.

Technical characteristics of installations. – The infrastructure that already exists at installations will have some influence on the type of BAT that can be installed and may also influence the cost of installing that BAT.

End-of-pipe improvements may initially be relatively cheap and quick to install, but in most cases, end-of-pipe technology will impose additional operating costs and will not offer the improved process efficiencies that could be realised from process-integrated measures. On the other hand, BAT improvements that are built into the process by process integration or adopting low waste technology can be costly because of the need to shut down production and rebuild the process.

The initial high cost of implementing process-integrated measures can be offset in the long run by the greater efficiency and reduced operating costs that may be realised, but differentiating the costs of process-integrated measures from other operating costs is, of course, more complicated (see Section 3.5).

Equipment lifetime - Some industries have long plant and equipment lifetimes, while in other industries, routine wear and tear and process innovations require items of equipment to be replaced more frequently. For some industry sectors, the economic lifetime is the determining factor for investment cycles.

A rapid implementation of BAT in sectors that routinely have long equipment operating lifetimes can impose a significant cost burden on those industries. In these cases, timing equipment upgrades to match existing replacement and investment cycles can be an effective means of upgrading to BAT in a cost effective way (See Section 5.5).

Barriers to entry or exit of the sector – If there are barriers to prevent the entry of new players to the market (such as high equipment or licensing costs), or there are barriers that prevent players leaving the market (exit barriers such as low liquidation returns on specialist assets etc.) this might be an issue that needs to be considered in the assessment. This is dealt with in more detail in Section 5.3.1.1.

5.2.2 Industry structure examples

The refineries sector is characterised by a small number of relatively large installations, many of which are older plants (see quotation below [23, EIPPCB, 2001]). In this sector, the most cost effective techniques are likely to be those that build on the existing infrastructure, such as modernising individual components within the process, to improve environmental performance.

"As a result of over-capacity in the European refinery sector, very few new oil refineries have been built in the last twenty-five years. In fact, only nine per cent of the existing refineries have been built in this period and only two per cent in the last ten years. Although most refineries will have had upgrades and new units built since they were first commissioned, their overall structure, and in particular items like the pattern of sewer systems, will have remained essentially unchanged."

In the Large Combustion Plant Directive [22, European Commission, 2001], a distinction was made between the emission limit values set for different sized plants. For example, a limit of 1700 mg SO_2/Nm^3 was set for large combustion plants up to 300 MW_{th}, and a limit of 400 mg SO_2/Nm^3 for plants greater than 500 MW_{th}, with a sliding scale of limits set for plants between these capacities.

5.2.3 Conclusion on industry structure

When carrying out an assessment of economic viability, understanding the industry structure might help to identify any constraints that may prejudice the implementation of the proposed BAT technique in the sector. Although there are no agreed or consistent descriptors or statistics that can be used to describe the industry structure of a sector, or how it might influence the determination of BAT, evaluation of the issues discussed above might allow a sector to build their case against a particular BAT proposal.

5.3 Market structure

The 'market structure' can influence the ability of the operator to pass on the cost of the environmental improvements from implementing BAT. The cost could be passed on to the customer by increasing the price of the product or, alternatively, passed on to suppliers by using the cost of environmental improvements as a bargaining tool to negotiate a lower price for raw materials. In situations where the margins are tight, and the costs cannot be passed on, then there may be a need for the TWG to consider the introduction of BAT with more caution. Some of the more significant issues for IPPC sectors are described below and there is also a description of how the market can be analysed using an established tool such as Porter's five forces theory.

5.3.1 Describing market structure

There are a range of issues worth considering when describing the 'market structure' of a sector. Many of these issues will involve a qualitative assessment, so it is difficult to be prescriptive as to when and to what extent these issues might influence the determination of BAT, however, the following issues are thought to be the most relevant:

Extent of the market - A 'local market' exists for commodities where there is a need for the goods or services to be close to the customer. This happens, for example, in the bulk sodium hypochlorite market, as the product degrades during storage or transport. A local market may also exist in a sector, for reasons such as the 'proximity principle', which, in the waste disposal sector means that any waste produced should be disposed of near the source of that waste.

In some sectors there may be a ‘regional market’, such as the one that exists for many of the chemicals that are produced and sold in Europe.

There is also a ‘global market’, in which operators are competing against competitors from all over the world and there is often strong pressure to keep the price down to minimise the threat of imports.

Understanding the extent of the market could be important, as it may determine the power that the customer has over the price of the commodity. In a local market, the customer might rely on the producer and may have limited control over the price. This will be less so in a ‘global market’, where prices are determined on the open market and European operators need to remain competitive against producers from outside Europe.

Elasticity in price - There may be an option of passing the costs on to the customer. Price elasticity is the term used by economists to describe how sensitive customers are to changes in price. For some products such as petrol and pharmaceuticals, customers might not be happy with price increases, but an increase does not have a significant impact on demand so the prices of these products are described as ‘inelastic’. If inelastic prices are a characteristic of that industry sector, then it can be relatively easy to pass the cost on to the customer.

Price changes in other commodities can have a far greater impact on demand and customers can be very sensitive to changes in price. The prices for these commodities are described as ‘elastic’.

Some issues that might affect the elasticity of the price of a commodity include the level of competition in the sector, the power of customers, the power of suppliers, and the ease with which the customer can switch to a substitute product (see below). When the price is elastic, it is difficult to pass on the costs to the customer so the producer will have to bear the brunt of any increase in costs.

Competition between products - In a sector where there is little or no differentiation between the commodity that is supplied by a large number of producers then competition is fierce. This might be the situation in industries such as metals, bulk chemicals, cement and power supply, where individual operators have little flexibility for setting or increasing prices. Where the threat of competition is large, opportunities to pass cost increases on to the customer are limited. Alternatively, if the sector is characterised by more specialist products, and where there is an opportunity to differentiate the operator’s product from that of the competition, then there may be more flexibility on the price. In these situations there is more opportunity for the operator to pass the costs of implementing BAT on to the customer.

Since the Directive should lead to a largely level playing field in the EU, this is not a significant issue as regards intra-EU competition. However, it may be an important issue if there is a considerable degree of EU-external competition (see above description on the ‘Extent of the market’).

5.3.1.1 Analysing the market using Porter’s five forces theory

There are several established methodologies that have been developed for analysing markets. One commonly used methodology is ‘Porter’s five forces theory’ [40, Porter, 1980]. Competitive forces determine industry profitability because they influence the prices, the costs, and the required investments of firms in an industry.

According to Porter's view, the rules of competition are embodied in five forces that shape the structure and intensity of competition:

- rivalry among existing firms
- the bargaining power of suppliers
- the bargaining power of buyers (or customers)
- the threat of substitute products or services
- the threat of new entrants.

The strength of these five forces varies from industry to industry, and can change as an industry evolves. Although this methodology was developed to assess the current state of an industry and allow managers to make strategic choices for the future, there are some elements from this model that could be used in the assessment of the market structure (for a detailed explanation of the theory see [40, Porter, 1980]), there are some elements of the assessment that might be useful for understanding an IPPC sectors ability to absorb or pass on the cost of implementing BAT. The key issues from the theory and the way that they might influence the determination of BAT are discussed below: [42, Vercaemst and De Clercq, 2003]

Rivalry among existing firms – Strong rivalry in a sector is likely to result in strong competition on price and may possibly constrain profit margins and, therefore, the sector's ability to absorb or to pass on the costs of implementing BAT. 'Competition', 'elasticity in price' and 'the extent of the market' which were discussed earlier might also be important. The concentration, or number of players in the market, can indicate the level of rivalry in the sector (the Herfindahl-Hirschmann[13] index can give an indication of the concentration in the sector). If overcapacity exists, then there will be limited opportunity to gain market share (this can sometimes be the case in sectors where products are sold to a standard specification, such as cement or bulk chemicals). Also, if there are high exit barriers (high shutdown costs, etc.) then these factors are likely to lead to strong rivalry within the sector.

Bargaining power of suppliers – If there are a large number of operators in a sector or a small number of customers then there is likely to be keen competition on price. Suppliers might also be in a powerful position if the operator is constrained by high switching costs (re-tooling or increased transport costs) and cannot switch suppliers easily. If a sector is only a small outlet for a supplier, then the supplier is again in a powerful position and can dictate the price and reduce the IPPC sector's ability to bargain for lower costs.

Bargaining power of buyers – If a sector is characterised by a small number of customers (the term 'buyers' is used by Porter) taking a significant market share of the sales, then the customers tend to be in a strong position and can exert more influence on the price. The ability of operators in the sector to pass on BAT costs may, therefore, be constrained. The customers might also hold power if there are low switching costs and they could quickly and easily switch to an alternative supplier (for example, if the product is fairly standard, e.g. bulk chemicals). Alternatively, when the product is a small fraction of the customers' costs, there may be more flexibility to pass the costs on.

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[13] Herfindahl-Hirschmann index: sum of the squared percentages of market shares of all firms in a sector. Markets in which the HHI is between 1000 and 1800 points are considered to be moderately concentrated, and those in which the HHI is in excess of 1800 points are considered to be concentrated [41, Carlton, 1990].

Threat of substitute products or services – Where the customer has the option of switching to an alternative product, then this may present a threat to the sector (for example, aluminium and plastics are increasingly being used as raw material in the production of cars, as a substitute for steel), then the opportunities to pass on increased costs to the customer are limited. The customer may initially be reluctant to make the switch because of the cost of re-tooling or process changes that they would have to make to accommodate the switch, but as BAT costs increase and these costs are reflected in product price increases, the threat of customers switching to substitute products may become more of an issue. When considering this aspect in the context of IPPC, this issue is not always significant, as it is about shifting 'market share' from one industry to another (e.g. from steel to non-ferrous metals and chemicals). However, it becomes relevant when considering only one particular sector, or when the threat from EU-external competition with substitute products is real.

Threat of new entrants – Highly profitable markets tend to attract new entrants. This threat tends to be constrained if there are high entry barriers (new equipment, access to distribution channels, customers switching costs, legal permits, etc.). This is likely to be of limited significance in the determination of BAT, because highly profitable markets are likely to be able to afford to implement BAT and new entries would be expected to implement BAT from start-up (and high cost BAT is, therefore, a barrier to new entrants).

5.3.2 Examples of Market Structure

This sort of detailed analysis has not been fully carried out to date but competition was one of the issues that were considered in the Large Volume Organic Chemical (LVOC) BREF [24, EIPPCB, 2002], which stated that;-

"Competition. *Basic petrochemical products are usually sold on chemical specifications, rather than on brand name or performance in use. Within any region different producers have different costs of production due to variations in scale, in feedstock source and type, and in process plant. There are few possibilities for product differentiation and so economies of scale are particularly important. Like other commodities, the basic petrochemical business is therefore characterised by competition on price, with the cost of production playing a very large part. The market for bulk chemicals is very competitive and market share is often considered in global terms."*

This is shown graphically by the following figure:

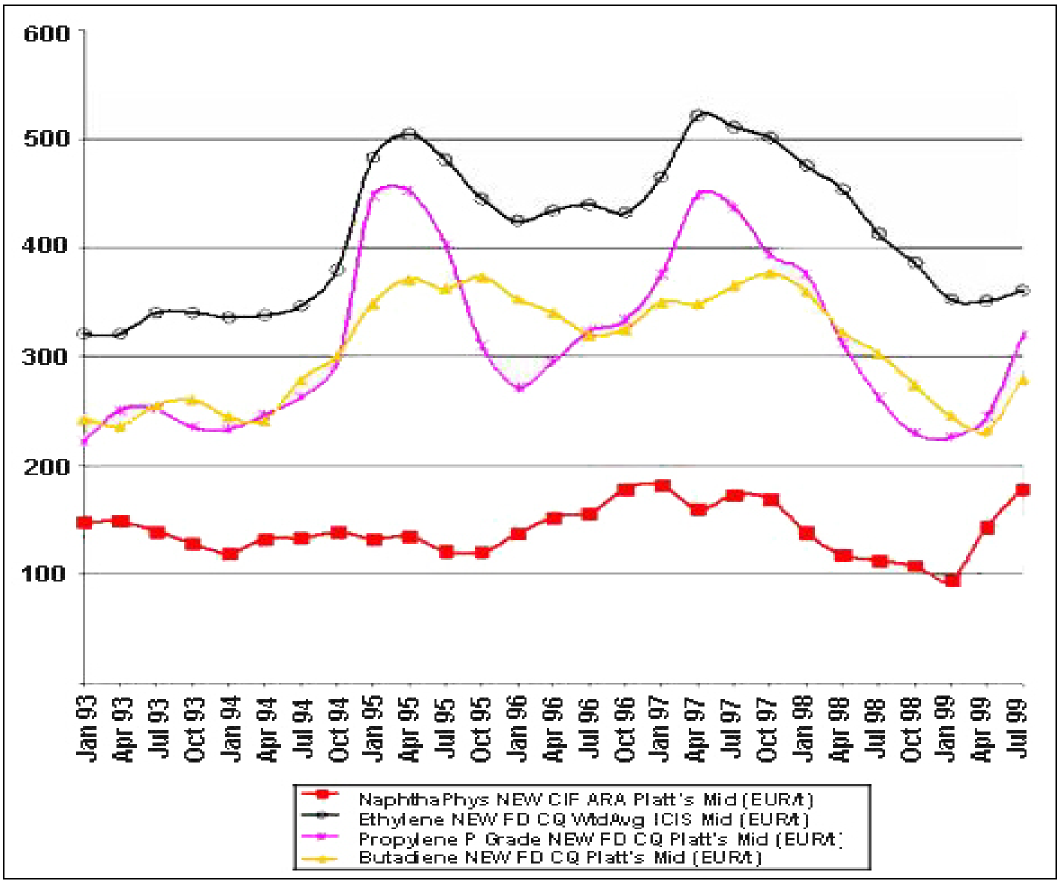

Figure 5.2: Price fluctuation of some petrochemicals

5.3.3 Conclusion on market structure

Consideration of the issues described here allows for a structured debate on market structure and the identification of those issues that are significant enough to influence the determination of BAT. It can give some indication of the sectors ability to pass the costs on to the customer. Although, in many cases, the assessment will be qualitative and detailed information needed to make a full assessment will not be available, an evaluation of the market structure will help identify any significant threats to the sector and allows the TWG to consider whether, or how, that might influence the determination of BAT.

5.4 Resilience

'Resilience' describes the sector's ability to absorb the increased costs of implementing BAT, while ensuring that it remains viable in the short-, medium- and long-term. In order to ensure this viability, operators in the sector will need to be able to generate sufficient financial returns on an ongoing basis to be able to invest in, for example, process development, product development, safety and environmental improvements, etc. Any increased costs associated with implementing BAT will either need to be absorbed by the industry or passed on to the customer; resilience describes the sectors ability to absorb these costs.

5.4.1 Describing resilience

There are several financial ratios that are routinely used to assess whether or not it is worth a company investing in improvements. Some of these financial ratios can be useful for evaluating resilience, but they can be difficult to apply to a sector rather than an individual company. When carrying out the assessment, the user will have to develop some way of defining an (hypothetical) average company (for example, by averaging the annual accounts for a sample of representative companies). This can, of course, easily be distorted by the selection of companies in the sample and the fact that individual companies record and express their financial information differently. These distortions are more likely where there are fewer operators in the sector or where there are some particularly badly or well performing companies. Where available, aggregated data for the sector concerned could be useful at European level. To avoid any distortions, the source of information and an analysis of that information both need to be fully documented so that any conclusions can be thoroughly audited and validated.

Annex 11 lists the most useful financial ratio formulas for this analysis. These financial ratios describe the liquidity, the solvency and the profitability of a company, where:

- **liquidity** - liquidity is a short-term measure of the health of the company and describes the company's ability to pay off its immediate liabilities. Annex 11 includes a method for calculating both the 'current ratio' and the 'quick ratio', which are routinely used to describe liquidity
- **solvency** - solvency of a company describes the company's ability to fulfil its obligations in the longer term. Calculations for 'solvency' and 'interest coverage' are included in the Annex 11
- **profitability** - profitability of a company is a measure of the profit margins that a company enjoys. Companies with higher profit margins will find it easier to absorb the costs of implementing BAT. Financial ratios for 'gross profit margin', 'net profit margin', 'return on capital employed' and 'return on assets' are also provided in the Annex 11.

When describing the resilience of a sector, the consideration of longer-term trends (5-10 years) is more useful; to ensure that short-term fluctuations are not allowed to distort the determination of BAT.

BAT costs as a percentage of product price could be a useful parameter for assessing the impact of introducing BAT. Although there is no pre-determined percentage which reflects BAT, this is a way of expressing the financial burden that implementing BAT will place on industry and it may be useful to consider this when evaluating the resilience of the sector. The costs of implementing BAT should be well known at this stage as the costs will already have been gathered, validated and processed according to the 'costing methodology' presented earlier in this document.

5.4.2 Examples of resilience

There are no evaluations of resilience that have been carried out to date in the BREF process, and there are no financial ratios that have been calculated for an individual sector. Although there are no direct examples of BAT costs as a percentage of profit, the following quotations are provided as illustrations:

Panorama of European Industry 1997 (Eurostat 1997) – Tannery Industry "*EU tanners' environmental costs which are estimated at about 5 % of their turnover……………......*"

Panorama of European Industry 1997 – Chemicals Industry *"In 1993, total environmental spending as a percentage of turnover amounted to 3.9 % in Western Europe. Total environmental spending is made up of operating costs (3.0 % of turnover) and capital spending (0.8 % of turnover)."*

The percentages quoted above were derived from European databases and submissions from industry sectors (total sectors – not just IPPC installations). There is no more detailed information available on how these percentages were actually calculated than is presented above. Environmental expenditures were **not reported** in the Panorama of European Business - 2000 Edition.

As a contrast to the percentages quoted above, in the incineration sector, a high proportion of investment costs are directly associated with meeting environmental protection standards. The relative proportion of costs associated with achieving BAT in this sector are, therefore, very high. For example, during a recent EIPPCB site visit to an incineration plant it was reported that 40 - 50 % of investment costs were associated with flue-gas cleaning equipment.

Some work has been carried out in Austria to establish environmental costs of installing selective catalytic reduction (SCR) for the glass and cement industries [55, Schindler, 2003] and these are presented in the tables below.

The glass industry

Assumptions: reduction rate of 1200 mg/Nm^3 of NO_X.
the lifetime of a catalyst in the glass industry is about four years

Costs:			
	electrical energy	EUR/kWh	0.07
	NH_4OH (25 % NH_3 Solution)	EUR/kg	0.12
	NH_3 liquid	EUR/kg	2.31
	catalyst	EUR/m^3	15000

	Units	Waste gas flowrates			
Waste gas flowrates	Nm^3/h	60000	30000	10000	10000
Estimated daily output (container glass)	tonnes/day	530	280	100	100
Annual production (working time: 8000 h)	tonnes/day	177000	93000	33000	33000
Reducing agent	NH_3	25 % solution	25 % solution	25 % solution	liquid
Investment	EUR	1154000	769000	385000	231000
Annual operating costs	EUR/year	181600	93320	34480	91120
Overall costs (6 % interest)	EUR/year	338390	197800	86789	122500
Costs per tonne container glass	EUR/tonne	1.96	2.18	2.64	3.92

The additional cost for SCR per tonne of product for the glass industry are roughly calculated to be between 0.2 % for domestic/special glass and 2 % for container/flat glass.

Table 5.1: Estimation of additional costs per tonne of container glass if SCR-technology is installed for several gas flowrates.

The cement industry

For estimating the implementation costs for SCR-technology in preheater cement plants, the following assumptions were made:

- capacity of cement kiln: 300000 tonnes clinker/year
- NO_X reduction: from 1000 to 200 mg/Nm^3 at 10 % O_2
- exhaust gas: 100000 Nm^3 for low dust SCR
- exhaust gas: 70000 Nm^3 for high dust SCR
- depreciation period: 15 years
- interest rate: 6 % and 10 %, calculated for both

	Low dust SCR		**High dust SCR**	
	Basis for calculation	EUR/tonne clinker	Basis for calculation	EUR/ tonne clinker
NO_X – reduction (10 % O_2)	1000 to 200 mg/Nm^3		1000 to 200 mg/Nm^3	
Investment costs EUR	2906892		2398186	
Specific investment costs		1[a] 1.5[b]		0.8[a] 1.2[b]
Catalyst	Operating period 10 years	0.13	Operating period 3 years	0.5
Maintenance and wear		0.30		0.20
Personnel costs		0.04		0.04
Treated gas stream	2.3 Nm^3/kg Clinker		1.5 Nm^3/kg Clinker	
Pressure loss	25 mbar		8 mbar	
Catalyst cleaning costs			Periodic cleaning	0.15
Energy for reheating	77.6 MJ/tonne clinker	0.24	0	0
Electrical Energy	3.3 kWh/tonne clinker	0.23	0.9 kWh/tonne clinker	0.06
NH_4OH, 25 % by mass	2.7 kg/tonne clinker	0.34	2.7 kg/tonne clinker	0.34
Assessed total cost	1000 to 200 mg/Nm^3	**2.2**[c] **2.7**[d]	1000 to 200 mg/Nm^3	**2.1**[c] **2.6**[d]
Assessed total cost[e]	1000 to 100 mg/Nm^3	**2.7**[c] **3.3**[d]	1000 to 100 mg/Nm^3	**2.0** [c] **3.1**[d]

[a] interest rate of 6 %
[b] internal calculated interest rate of companies 10 %
[c] invest costs –10 %; per 6 %
[d] invest costs +10 %; per 10 %
[e] assessed total costs for 100 mgNO_X/m^3 HMW (c. + 20 %)

The additional cost for SCR per tonne of product for the cement industry was calculated to be between 3 - 5 % of the product price (EUR 65/tonne cement).

Table 5.2: Calculation for the costs of implementing low dust SCR and high dust SCR in the cement industry.

5.4.3 Conclusion on resilience

Some financial indicators are provided, which might be useful in the analysis. When analysing these financial indicators, unless aggregated data is available there is a need to derive a set of accounts for an ‘average company’, and there is then, of course, a danger that this might not be representative of the whole sector. To avoid any distortions, the process needs to be fully documented so that it can be validated and audited by the TWG.

A consideration of the resilience of a sector is useful for assessing whether operators could absorb any increase in costs due to implementing BAT. When resilience of the sector has been analysed, the TWG can determine whether this parameter is sufficiently important to influence the determination of BAT.

5.5 Speed of implementation

If after assessing the industry structure, market structure and resilience of the sector, the package of BAT techniques is determined to be viable, but there are still concerns about their introduction, the TWG might consider evaluating the speed with which BAT is implemented, as this can be a critical issue for industry. The Directive sets out time-scales for the implementation of the Directive and granting of permits which must be observed, but upgrading to BAT standards, particularly in sectors where there is a significant investment required, takes time and planning. Immediate upgrades can be difficult to plan for and may cause difficulties for industry if there is no opportunity to harmonise the upgrade with existing business planning and investment cycles. Techniques that require a significant capital investment or significant plant and infrastructure changes will, of course, need more time.

The speed of implementation is not normally an issue for new installations as new plants will be expected to incorporate or can be readily adapted to incorporate the best environmental techniques. There is, therefore, a need to distinguish between new and existing installations in this evaluation.

It is also useful to consider the marginal costs of upgrading to BAT when discussing the speed of implementation. Those sectors that have made significant environmental investments in the past might have a high marginal cost of achieving BAT compared to those that have not made so much investment in the past. It can be more cost effective to address those plants that have made few investments in the past even though they will have a greater 'distance to target' to achieve BAT standards. Easing the introduction of BAT through setting a longer time scale for implementation should not be seen as an opportunity to reward reluctant companies for their bad performance in the past.

5.5.1 Describing speed of implementation

Consideration of the following time scales is useful when determining the speed of implementation.

- **short-term** (typically this could be weeks to months) – for many techniques, the time scales required for implementation will not require any special consideration for the timing of their implementation. These techniques are typically ones that can be implemented quickly (and probably at low cost), for example small abatement units such as oil separators, management techniques, or raw material changes, provided in the latter case, that such a change does not entail extensive modifications to the processing plant or changes to product specification, both of which could mitigate against rapid change
- **medium-term** (typically this could be from months to a year or more**)** – there are some techniques that might need a little more time to implement because of the cost or planning and the level of scheduling that is necessary. This is normally the case with end-of-pipe techniques, for example abatement units such as bag filters which can usually be installed without the need for an extended process shutdown, but will still need some time for planning and to fit in with the operators investment cycle
- **long-term** (typically this is a number of years) – when significant changes to the production process or plant reconfiguration are required such as rebuilding process plants or waste water treatment, for example, then the capital investments are likely to be significant. Early shutdown and rebuild of processes can be expensive for industry, especially those that normally have long operating lifetimes. Timing upgrades to coincide with existing replacement and investment cycles can be an effective means of implementing the technique in a cost-effective way, but this needs to be balanced against the effect of delaying the improvement to the environment.

In all these cases there may be alternatives, typically process-integrated techniques, which can ultimately be more cost effective than unit end-of-pipe techniques, but which require more time to implement than the end-of-pipe units.

5.5.2 Examples of speed of implementation

A clear example can be found in the BREF on the Glass Manufacturing Industry [25, EIPPCB, 2001]. The TWG agreed that whilst many improvements to the operation of the furnace, including the installation of secondary techniques, are possible during the operation campaign, major changes to the melting technology could be most economically implemented if they were timed to coincide with routine furnace rebuilds. This, of course, meant a delay in the environmental improvement that implementing BAT would deliver, especially in those industries where plants had a long operational life. The TWG involved in the development of the Glass BREF believed that the frequency with which furnace rebuilds occur in the industry (typically every 8 to 12 years), and the high cost of early replacement justified this approach.

5.5.3 Conclusion on speed of implementation

The speed with which new BAT techniques are implemented is one of the most critical issues for industry, particularly when implementing the more expensive techniques. Some sectors routinely have long operating lifetimes for their equipment and if implementing BAT forces early shutdown and replacement of that equipment, it can impose a significant cost burden on those industries. In particular, short time scales to implement expensive techniques can cause difficulties for industry raising capital and planning for the introduction of the technique. If this is thought to be a critical issue, then timing any upgrades with existing replacement and investment cycles can be a cost effective means of implementing techniques.

If the speed of implementation is thought to be a critical issue for this sector, then those carrying out the assessment will have to build the case for it so that the decision-maker can strike a balance between protection of the environment and fitting in with a reasonable planning and investment cycle for industry. The findings of the analysis of the industry structure, the market structure and resilience are likely to give an indication as to whether the speed of implementation is likely to be a critical issue.

5.6 Conclusion on economic viability in the sector

Whilst the basic concept is an integral part of the determination of BAT, an in-depth assessment of ‘economic viability’ should not be carried out unless there is genuine concern as to which environmental protection techniques can feasibly be implemented in the sector. There are no hard and fast rules that can be applied across the range and diversity of industrial sectors covered by the Directive and this analysis is therefore likely to be a difficult and time consuming process. The factors identified in this chapter are seen as the most critical issues for ensuring ‘economic viability in the sector’ when determining BAT. If there are genuine concerns about the future viability of a sector, then the factors identified in this chapter should help focus the debate so that the important issues can be exposed and discussed.

In situations where ‘economic viability’ is identified as a critical issue, it should be considered in more depth in the determination of BAT. BAT often involves implementing a basket of techniques, which may not all require investment and which will often include management based techniques. Ultimately it is the overall costs of achieving BAT, possibly including both high cost and low cost elements which affects economic viability of BAT. There may also be an opportunity to minimise the financial impact of implementation by defining longer time-scales for the introduction of high-cost techniques, so that implementation can coincide with routine plant and equipment rebuilds. Understanding the critical issues for the sector allows the decision-maker to determine the optimum combination of techniques that can deliver a high level of protection for the environment as a whole without jeopardising ‘economic viability’.

Once the critical issues for the sector have been analysed and exposed in the assessment, then it is expected that the Technical Working Group can debate these critical issues and decide whether, or how they should influence the determination of BAT.

6 CONCLUDING REMARKS

The information exchange process for the development of this document started in May 2000 and extended through until the end of 2004. Work to develop some of the more technical methodologies set out in the document was carried out within specialist subgroups of the TWG. The first full draft of the document was issued for consultation in November 2002, and the second draft was issued for consultation in September 2003.

Rather than developing new methodologies to address the economic and cross-media issues inherent to the concept of BAT, the approach was adopted to find out what was available and used already and to bring those methodologies together in a way that could suit the requirements of the Directive for determination of BAT at the sector level, or possibly to help determine permit conditions for individual installations.

The methodologies that are described here are fairly robust and lead the user through the decision-making process in a structured way. The framework that is set out in this document should help set out the issues transparently and set out the costs and benefits of implementing alternative techniques. Even so, simply applying the methodologies alone will not be sufficient to make the decision and there is still a need for expert judgement to determine which techniques are BAT. There is a need for expert judgement throughout the decision-making process as there are limitations to the methodologies, or in some cases, there may be important issues that need to be considered but which are not covered by the methodologies set out here. The key requirement which runs through all of the methodologies is that transparency must be maintained throughout. This transparency ensures that the justification for the decisions taken can be seen clearly, and can be understood, validated and audited at every stage of the process.

In the development of the methodologies for evaluating the cross-media effects, the starting point was ‘life cycle assessment’ methodologies that are already established and used. There were some difficulties with using this approach because of the need to restrict the assessment within the boundaries of the IPPC process and there were also concerns about some of the very general assumptions that were made in the development of the life cycle assessment. To address these concerns, the methodology described here was refined and augmented with some of the methodologies that are currently used in Member States. In pulling these methodologies together and developing the cross-media methodology for the document, there was a need to understand the limitations, validate them, to identify any assumptions, and then explain them in a transparent way.

The user should be able to carry out the evaluation without the use of software. This is to ensure ease of use and to allow for the results to be set out transparently and audited where necessary. The sources of information to support the methodology are presented in the Annexes to this document. Significant effort has gone into identifying the most up to date, valid and relevant information in these Annexes, but these numbers will change over time, and wherever possible, links to the relevant sources where users can find more up to date information are provided.

It was difficult to find good examples to illustrate the methodology and the interpretation of the information that the methodology delivers. To illustrate the methodologies throughout this document, two examples are included as Annexes to this document although they are only illustrative. Throughout their development, opportunities for testing the methodologies have been explored, particularly for the cross-media methodology. In the real world there have been very few examples that would require the detailed assessment set out here, and the best environmental option will normally be determined with a simple evaluation of the alternative options. Where this is the case, setting out the justification transparently should be sufficient to support the decision.

When developing the costing methodology, several factors needed to be taken into consideration, for instance, cost accounting techniques vary between Member States and operators may also account for costs in different ways. This can make comparisons very difficult, so there was a need to harmonise these cost accounting techniques to allow fair comparisons to be made between alternative options. In the development of the costing methodology, there was an opportunity to build on work that had been carried out in the past by the European Environment Agency. This work was refined and developed to fit within the requirements of the IPPC Directive by a sub-group within the TWG and consequently the costing methodology has been well received and accepted. The methodology sets out the steps necessary to gather and validate the cost data, to identify the cost components and then to process and present the cost information. Although there is some flexibility in how these steps are carried out the key requirement here (as it is throughout the document) is that the information needs to be presented transparently. This is to ensure that each of the alternative options can be evaluated fairly and audited at any stage in the process.

Once the environmental effects have been evaluated by the cross-media methodology and the costs gathered and presented using the costing methodology, there is likely to be a need to compare them. Chapter 4 describes cost effectiveness, which is a fairly straightforward technique for comparing the environmental benefit a technique will provide against the costs of implementing that technique. However, this may not provide sufficient information to determine whether the costs are reasonable. To address this issue, some methods of setting benchmark reference values for cost effectiveness of techniques for some air pollutants are discussed. Although there are significant uncertainties that surround the value of these benefits, applying the methods might provide useful information that could aid the evaluation and simplify the decision making process. There is much concern expressed over the values for external costs available. The methods of deriving such costs and some of the assumptions made have attracted much criticism.

In the determination of BAT, there might be a need to determine whether the techniques put forward meet the definition of ‘available’ in the Directive which requires that “those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions”. Chapter 5 on ‘economic viability in the sector’ sets out those issues that are thought to be most critical in the assessment and allows for a structured debate to be put forward and assessed. For this evaluation, there was little agreement as to what should be considered in the assessment. To address this, the methodology was developed based on discussions and proposals within the TWG, an evaluation of how these decisions had been taken in the past, the work of DG Enterprise on the impact of BAT on the Competitiveness of European Industry and drafts and re-drafts of the chapter reviewed and commented on by the various stakeholders in the information exchange process.

Chapter 5 thus sets out how to evaluate whether the costs of implementing BAT can be absorbed (‘resilience’) or passed on to the customer (‘industry structure’, ‘market structure’). If the costs can be absorbed or passed on, but there are still concerns about the financial impact of introducing the new techniques, then there is an opportunity to evaluate whether implementation over a longer time scale (‘speed of implementation’) is a feasible way of easing their introduction.

The assessment of economic viability will only be necessary when determining BAT; the Directive does not make any provision for evaluating economic viability other than at sector level. An in-depth assessment would only be expected in situations where economic viability is identified as a critical issue. The burden of proof for challenging whether techniques are ‘economically viable’ rests with whoever objects to the proposed BAT techniques. These objections are only likely to arise when techniques are considered to be too expensive (usually from the industry that would be expected to implement them). It is expected that the objector would put forward the justifications for their objections in the structured way that is set out here.

The EC is launching and supporting, through its RTD programmes, a series of projects dealing with clean technologies, emerging effluent treatment and recycling technologies and management strategies. Potentially these projects could provide a useful contribution to future BREF reviews. Readers are therefore invited to inform the EIPPCB of any research results which are relevant to the scope of this document (see also the preface of this document).

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GLOSSARY

Term	Explanation
Additional cost/expenditure	This term refers to the difference between all costs incurred under the base case or existing situation versus those costs incurred when implementing the other options under consideration.
ADI	Acceptable Daily Intake.
Advantage(s)	See *benefits*.
Annual capital cost	An equal, or uniform, payment made each year over the useful life of the proposed technique. The sum of all the payments has the same *present value* as the initial investment expenditure. The annual capital cost of an asset reflects the opportunity cost to the investor of owning the asset.
Avoided costs	The value of any savings in labour, energy or materials input costs relative to the base case, resulting from operating the technique.
Base case	The existing situation. The projection of the base case is sometimes referred to as the 'business-as-usual' or 'baseline' scenario.
Base year	In the context of processing time-dependent data such as costs or emissions, the base year is the year selected for assembly of the raw input data. The base year serves as the year from which projections of the base case are made.
BAT	Best Available Techniques.
Benefits	Used in this document synonymously with '*advantages*' to mean the positive or negative environmental effects considered to be due to implementation of a technique or other environmental measure.
BREF	BAT reference document.
Capital recovery factor	A factor used to calculate the annual capital costs of an environmental protection technique. A capital recovery factor may equally be used to determine the equivalent annual cost of the stream of annual cash outflows (i.e. the initial investment expenditure and the series of 'net' annual operating and maintenance costs) incurred over the useful life of an environmental protection technique.
Cash flow	For a given year, the cash flow associated with an environmental protection technique or measure is the difference between money received and money paid out. Once the environmental protection technique is operational, the cash flow in a given year will cover the operating and maintenance costs less income from the sale of by-products and any associated cost savings. Similarly, before the technique is operational, the cash flow will only include investment expenditures. Cash flows only include costs as they are incurred. Depreciation charges are not cash flows.
Constant prices	See *real prices*.
Contribution analysis	Comparison of the results using a standard reference such as the total European load in order to give an insight into the relative significance of the results.
Cross-media conflicts	Resolving issues where there are competing environmental effects, or effects that are difficult to compare (for example, NO_X reduction versus energy consumption).
Cross-media effects	The calculation of the environmental impacts of water, air or soil emissions, energy use, consumption of raw materials, noise and water extraction, etc.
Current prices	See *nominal prices*.
Deflation	A decrease in the general price level or an increase in the purchasing power of money.
DEM	German mark
Depreciation charge	Capital goods (e.g. pollution abatement equipment) are typically used up over a period of time. Each year, a portion of the usefulness of these assets expires, therefore a portion of the original investment expenditure should be recognised as an annual (capital) cost. The term 'depreciation' refers to the systematic allocation of the cost over the accounting periods of its useful life.

Term	Explanation
Direct costs	Direct costs refer to those costs that can be primarily attributed to the proposed technique, i.e. direct costs measure the value of the additional resources used to purchase, install, operate and maintain the technique(s).
Discount rate	The rate used to discount future cash flows to their present value.
Discounted cash flow	The present value of expected future cash flows.
Discounting	The process of determining the present value of future cash flows.
DKK	Danish krone
Economic life	The time at which the marginal costs of operating and maintaining an environmental protection technique exceed the marginal benefits provided by the asset – usually because other factors, such as technological change or changes in economic circumstances, may render the asset obsolete or inadequate. The economic life of an environmental protection technique may differ from its *technical life*; the economic life is typically shorter than the technical life.
Economies of scale	Greater efficiencies through increasing outputs. For example, if an operator can lower its production costs by buying in bulk or increasing the capacity of the production line, etc.
Efficiency	A measure of the effectiveness of a technique to achieve a particular result. In some cases it may be expressed as a ratio of input to output.
EIPPCB	European IPPC Bureau.
Elasticity in price	Describes how demand for a commodity changes as the price increases. If demand reduces dramatically as the price increases, then the commodity is elastic, if it does not then it is inelastic. If the percentage change in the quantity demanded is more than the percentage change in price then the commodity is price elastic. It can be expressed as a dimensionless number $[(\Delta D/D)/(\Delta P/P)]$ where ΔD is the change in demand D and ΔP the change in price P.
Emission	The direct or indirect release of substances, vibrations, heat or noise from individual or diffuse sources in the installation into the air, water or land.
Emission factor	The estimated average emission rate of a given pollutant for a given source, relative to units of activity.
Environmental themes	Used in this document to describe the effects or impacts that can be collated together for assessment. In the cross-media methodology the following themes are used: - human toxicity - global warming - aquatic toxicity - acidification - eutrophication - ozone depletion - photochemical ozone creation - abiotic depletion. These environmental themes are analogous to impact categories referred to in ISO 14042.
Equivalent annual cost	See *annual capital cost*.
EUR	Euro
Expenditure	The actual cash-flows. Expenditure in a given year can relate both to investment (capital expenditure) and to operating costs and consumption.
Externalities	Economic cost not normally taken into account in markets or in decisions by market players. A negative externality would be, for example, where there is a need to repaint surfaces more frequently because of air pollution causing deterioration to the painted surface. It is not the polluter that would pay for the repainting, so it is an external cost or externality.
Fees	Fees are to be paid to an institution or public establishment (fees for local waste and waste water disposal, fees for permission or supervision of environmental protection installations).
GBP	Pounds sterling.

Term	Explanation
GDP	Gross Domestic Product.
General price level	The weighted average price of all goods and services in the economy, relative to their prices at some fixed date in the past. The general price level shows what is happening to prices on average, not what is happening to the prices of individual goods. Changes in the general price level are measured by the *consumer price index* with the base year assigned a value of 100.
GJ	Gigajoule (1GJ = 10^9 joule).
HFO	Heavy fuel oil.
IEF	Information Exchange Forum (informal consultation body in the framework of the IPPC Directive).
Indirect costs	Indirect costs refer to those costs associated with changes in demand in related markets or sectors of the economy through backward and forward production linkages. For example, the (direct) expenditures on an environmental protection technique may induce changes in demand for certain resources and related services throughout the economy. The net value of these induced changes is an indirect cost of the investment.
Inflation	An increase in the general price level of a product or service or a decrease in the purchasing power of money.
Interest cost (charge)	A charge made for the use of money (i.e. the interest on loans or investment). The yearly interest charge on the unpaid capital balance is one part of the annual capital cost.
Interest rate	The ratio of the interest charged in any one time period to the original investment expenditure.
Investment expenditure	The total expenditure made in a given year to purchase pollution control or plant equipment from a supplier, and all expenditures associated with installing the equipment and making it operational. This includes the purchase of land, general site preparation etc.
LC50	Lethal concentration 50. The lowest concentration of a substance in water or ambient air in milligrams per litre sufficient to cause death in 50 % of the test population within a defined period (e.g. 96 hours for fish, 48 hours for daphnia).
LD50	Lethal dose 50. The lowest dose of a substance administered to species such as mice and rats sufficient to cause death in 50 % of the test population within a defined period (no more than 14 days), expressed in milligrams of test substance per kilogram of bodyweight.
Measure	Technique or combination of techniques.
MJ	Megajoule (1MJ = 1000 kJ = 10^6 joule).
MTC	Maximum Tolerable Concentrations.
NOAEL	No Observed Adverse Effect Levels.
NOEC	No Observed Effect Concentration.
Nominal (current) prices	Prices measured in terms of purchasing power of the date in question. Nominal prices have not been adjusted for the effects of inflation.
Nominal discount/interest rate	Nominal or current discount rates refer to the rates ruling when they were measured. Such rates have not been adjusted for the effects of inflation.
Normalisation	See *contribution analysis*.
Operating and maintenance costs	The cost of the energy, labour, materials and environmental services required to operate and maintain the proposed technique during a single year. Operating and maintenance costs can include fixed annual costs associated with administration, insurance premiums and other general overheads. However, they exclude any costs associated with the financing and depreciation of the plant or equipment. These are covered through the use of a capital recovery factor when determining total annual costs or annual capital costs. As operating and maintenance costs are incurred yearly throughout the useful life of the technique, they are also known as *recurring* costs.
Opportunity cost	The value of a scarce resource in its next best alternative use. The true economic cost of a resource is given by its opportunity cost.

Term	Explanation
Opportunity cost of capital	The expected rate of return that is foregone by investing in the proposed technique rather than in the best alternative investment.
Overhead costs	Overhead costs are costs that cannot be related directly to an individual object or cost unit. Generally they are cleared as overtime rates or percentage rates to cost centres and later, in the calculations, are divided between the products, where they are booked as overhead costs of the cost unit (for example administration costs, etc.).
PNEC	Predicted No Effect Concentrations. The concentration at which no toxic effect is observed.
pollutant	Individual substance or group of substances which can harm or affect the environment.
Pollution source	The emission source. Pollution sources can be categorised as (i) point, or concentrated sources; (ii) dispersed sources or fugitive emissions; and (iii) line sources, including mobile (transport) and stationary sources.
Price Elasticity	See *elasticity in price*
Present value	The amount of money today considered equivalent to a cash inflow or outflow expected to take place in the future. That is, the discounted value of future cash flows.
Purchasing power	The ability of money to buy goods and services. As the general price level rises, the purchasing power of money declines. Thus, in periods of inflation, an ever-increasing amount of money is required to represent a given amount of purchasing power.
Real (Constant) prices	Real or constant price variables adjust nominal variables for changes in the general price level. They are prices that have been adjusted for inflation.
Real discount/interest rate	A nominal discount/interest rate adjusted for inflation so that it represents an increase in purchasing power. The real discount or interest rate measures how much extra consumption you can have in period 2 if you give up some consumption in period 1.
Revenues	The (annual) income generated through, for example, the sale of materials recovered or energy generated from the operation of a proposed technique.
SEK	Swedish krona.
TDI	Tolerable Daily Intake
Technical life	The estimated ‘physical’ life of a technique, i.e. the time it takes for the asset to literally wear out due to ‘physical’ deterioration. The estimated technical life of a technique is a function of the assumed maintenance regime. A good repair policy may lengthen the life of the asset.
TJ	Terajoule (1 TJ = 10^{12} joule).
Total annual cost	The total annual cost of a technique corresponds to the uniform annual payment required to cover both the net annual operating and maintenance costs, as well as the annual capital costs (in the form of capital recovery and the cost of capital).

ANNEXES

ANNEX 1 - HUMAN TOXICITY POTENTIALS

List of non-dimensional toxicity factors for some potentially relevant air pollutants

Factors in this list are intended only to be used for assessing general toxicity effect units for comparing techniques on a sectoral basis. They are not intended for other purposes.

Application of these factors for calculating the Human Toxicity Potential of a technique/process is discussed in Section 2.5.1:

Simplification and Limitations of the table:

The method relies on certain simplifications such as (a) there is no distinction for type of toxicity effect (b) no analysis of synergistic or antagonistic effects is incorporated and (c) only chronic (long term) effects are incorporated. The factors can only provide a broad indication of relative toxicity.

The factors are derived from German occupational exposure limits, divided by the respective figure for lead. Reference source: TRGS-900. Technische Regeln für Gefahrstoffe. Grenzwerte in der Luft am Arbeitsplatz "Luftgrenzwerte". Stand April 2003. German TRGS-values = Limit values in the air at working places (includes risk based MAK = maximum working place concentrations, and TRKs = Technical Guideline values: working place values that can be technically achieved at working places.

	Substance	Human Toxicity Factor
1	1,1,1-Trichloroethane	11000.00
2	1,2,4-Trichlorobenzene	38.00
3	1,2-Dichlorobenzene	610.00
4	1,2-Dichloroethane	200.00
5	1,4-Dichlorobenzene	3000.00
6	1,4-Dioxane	730.00
7	2,2'-Oxydiethanol	440.00
8	2-Aminoethanol	51.00
9	2-Butoxyethanol	980.00
10	2-Ethoxyethanol	190.00
11	2-Ethoxyethyl acetate	270.00
12	2-Methoxyethanol	160.00
13	2-Methoxyethyl acetate	250.00
14	Acetaldehyde	910.00
15	Acetone	12000.00
16	Acetonitrile	340.00
17	Acrylaldehyde	2.50
18	Acrylamide	0.30
19	Acrylic acid	
20	acrylonitrile	70.00
21	Ammonia	350.00
22	Aniline	77.00
23	Anisidine, o- and p-	5.10
24	Antimony and compounds	5.00

	Substance	Human Toxicity Factor
25	Arsenic and compounds	1.00
26	Benzene	32.50
27	Benzo-a-pyrene	0.05
28	Benzyl butyl phthalate	30.00
29	Beryllium and compounds (as Be)	0.02
30	bis(2-ethylhexyl) phthalate	100.00
31	Buta-1,3-diene	110.00
32	Butan-2-one	6000.00
33	Butane	24000.00
34	Butyl acetate	960.00
35	Cadmium and compounds	0.15
36	Carbon disulphide	300.00
37	Carbon monoxide	350.00
38	Carbon tetrachloride	640.00
39	Chlorine	15.00
40	Chlorobenzene	470.00
41	Chloroform	
42	Chloromethane	1000.00
43	Chromium VI compounds	0.50
44	Cobalt and compounds	1.00
45	Copper dusts and mists (as Cu)	10.00
46	Cresols, all isomers	220.00

	Substance	Human Toxicity Factor
47	Cumene	2500.00
48	Cyclohexane	7000.00
49	Cyclohexanone	800.00
50	Dichloromethane	3500.00
51	Dimethyl sulphate	1.00
52	Dimethylamine	37.00
53	Dimethylaniline, NN-	250.00
54	Dimethylformamide	300.00
55	Diphenylamine	50.00
56	Ethanol	9600.00
57	Ethyl acetate	15000.00
58	Ethyl acrylate	210.00
59	Ethylamine	94.00
60	Ethylbenzene	4400.00
61	Fluoride (as F)	25.00
62	Formaldehyde	6.20
63	Hydrazine	1.30
64	Hydrogen chloride	80.00
65	Hydrogen fluoride	-
66	Hydrogen sulphide	140.00
67	Isocyanates (as NCO)	0.00
68	Lead	1.00
69	Manganese and compounds	5.00
70	Mercury and compounds, except mercury alkyls, as Hg	0.10
71	Methyl acrylate	180.00
72	Methanol	2700.00
73	Methyl acetate	6100.00
74	Methyl methacrylate	2100.00
75	Methyl-tert-butyl-ether	-

	Substance	Human Toxicity Factor
76	Naphthalene	500.00
77	n-Hexane	1800.00
78	Nickel and inorganic compounds	0.50
79	Nitrobenzene	50.00
80	Nitrogen dioxide	95.00
81	Nitrogen monoxide	300.00
82	NN-Dimethylaniline	250.00
83	Ozone	2.00
84	Phenol	190.00
85	Phosgene	0.82
86	Propan-2-ol	5000.00
87	Pyridine	160.00
88	Sodium hydroxide	20.00
89	Styrene	860.00
90	Sulphur dioxide	13.00
91	Tetrachloroethylene	3450.00
92	Tin compounds, inorganic, except SnH_4	20.00
93	Toluene	1900.00
94	Trichloroethylene	2700.00
95	Trimethylbenzenes, all isomers or mixtures	1000.00
96	Vanadium	5.00
97	Vinyl acetate	360.00
98	Vinyl chloride	50.00
99	Xylene, o-, m-, p- or mixed isomers	4400.00
100	Zinc oxide	50.00

ANNEX 2 - GLOBAL WARMING POTENTIALS

The following table gives ‘direct global warming potentials’ (mass basis) relative to carbon dioxide of gases whose lifetimes have been adequately characterised.

Gas	Chemical formula	Atmospheric lifetime (years)	Global warming potential (100 year time horizon)
Carbon dioxide	CO_2		1
Methane	CH_4	12	23
Nitrous oxide	N_2O	114	296
Chlorofluorocarbons			
CFC-11	CCl_3F	45	4600
CFC-12	CCl_2F_2	100	10600
CFC-13	$CClF_3$	640	14000
CFC-113	CCl_2FCClF_2	85	6000
CFC-114	$CClF_2CClF_2$	300	9800
CFC-115	CF_3CClF_2	1700	7200
Hydrochlorofluorocarbons			
HCFC-21	$CHCl_2F$	2	210
HCFC-22	$CHClF_2$	11.9	1700
HCFC-123	CF_3CHCl_2	1.4	120
HCFC-124	CF_3CHClF	6.1	620
HCFC-141b	CH_3CCl_2F	9.3	700
HCFC-142b	CH_3CClF_2	19	2400
HCFC-225ca	$CF_3CF_2CHCl_2$	2.1	180
HCFC-225cb	$CClF_2CF_2CHClF$	6.2	620
Hydrofluorocarbons			
HFC-23	CHF_3	260	12000
HFC-32	CH_2F_2	5	550
HFC-41	CH_3F	2.6	97
HFC-125	CHF_2CF_3	29	3400
HFC-134	CHF_2CHF_2	9.6	1100
HFC-134a	CH_2FCF_3	13.8	1300
HFC-143	CHF_2CH_2F	3.4	330
HFC-143a	CF_3CH_3	52	4300
HFC-152	CH_2FCH_2F	0.5	43
HFC-152a	CH_3CHF_2	1.4	120
HFC-161	CH_3CH_2F	0.3	12
HFC-227ea	CF_3CHFCF_3	33	3500
HFC-236cb	$CH_2FCF_2CF_3$	13.2	1300
HFC-236ea	CHF_2CHFCF_3	10	1200
HFC-236fa	$CF_3CH_2CF_3$	220	9400
HFC-245ca	$CH_2FCF_2CHF_2$	5.9	640
HFC-245fa	$CHF_2CH_2CF_3$	7.2	950
HFC-365mfc	$CF_3CH_2CF_2CH_3$	9.9	890
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	15	1500
Chlorocarbons			
CH_3CCl_3		4.8	140
CCl_4		35	1800
$CHCl_3$		0.51	30
CH_3Cl		1.3	16
CH_2Cl_2		0.46	10

Gas	Chemical formula	Atmospheric lifetime (years)	Global warming potential (100 year time horizon)
Bromocarbons			
CH_3Br		0.7	5
CH_2Br_2		0.41	1
$CHBrF_2$		7	470
Halon-1211	$CBrClF_2$	11	1300
Halon-1301	$CBrF_3$	65	6900
Iodocarbons			
CF_3I		0.005	1
Fully fluorinated species			
SF_6		3200	22200
CF_4		50000	5700
C_2F_6		10000	11900
C_3F_8		2600	8600
C_4F_{10}		2600	8600
$c-C_4F_8$		3200	10000
C_5F_{12}		4100	8900
C_6F_{14}		3200	9000
Ethers and halogenated ethers			
CH_3OCH_3		0.015	1
$(CF_3)_2CFOCH_3$		3.4	330
$(CF_3)CH_2OH$		0.5	57
$CF_3CF_2CH_2OH$		0.4	40
$(CF_3)_2CHOH$		1.8	190
HFE-125	CF_3OCHF_2	150	14900
HFE-134	CHF_2OCHF_2	26.2	6100
HFE-143a	CH_3OCF_3	4.4	750
HCFE-235da2	$CF_3CHClOCHF_2$	2.6	340
HFE-245cb2	$CF_3CF_2OCH_3$	4.3	580
HFE-245fa2	$CF_3CH_2OCHF_2$	4.4	570
HFE-254cb2	$CHF_2CF_2OCH_3$	0.22	30
HFE-347mcc3	$CF_3CF_2CF_2OCH_3$	4.5	480
HFE-356pcf3	$CHF_2CF_2CH_2OCHF_2$	3.2	430
HFE-374pc2	$CHF_2CF_2OCH_2CH_3$	5	540
HFE-7100	$C_4F_9OCH_3$	5	390
HFE-7200	$C_4F_9OC_2H_5$	0.77	55
H-Galden 1040x	$CHF_2OCF_2OC_2F_4OCHF_2$	6.3	1800
HG-10	$CHF_2CHF_2OCF_2OCHF_2$	12.1	2700
HG-01	$CHFOCFCFCHFOCFCFOCHF_2$	6.2	1500

Annex 2. Table 1 [2, Intergovernmental Panel on Climate Change, 2001]

http://www.grida.no/climate/ipcc_tar/wg1/248.htm

The following table lists 'direct global warming potentials' (mass basis) relative to carbon dioxide of gases whose lifetimes have been determined only via indirect means rather than by laboratory measurements, or for whom there is uncertainty over the breakdown processes. Radiative efficiency is defined with respect to the whole sky.

Gas	Chemical Formula	Estimated lifetime (years)	Global Warming Potential (100 year time horizon)
NF_3		740	10800
SF_5CF_3		>1000 *	>17500
$c\text{-}C_3F_6$		>1000 *	>16800
HFE-227ea	$CF_3CHFOCF_3$	11	1500
HFE-236ea2	$CF_3CHFOCHF_2$	5.8	960
HFE-236fa	$CF_3CH_2OCF_3$	3.7	470
HFE-245fa1	$CHF_2CH_2OCF_3$	2.2	280
HFE-263fb2	$CF_3CH_2OCH_3$	0.1	11
HFE-329mcc2	$CF_3CF_2OCF_2CHF_2$	6.8	890
HFE-338mcf2	$CF_3CF_2OCH_2CF_3$	4.3	540
HFE-347mcf2	$CF_3CF_2OCH_2CHF_2$	2.8	360
HFE-356mec3	$CF_3CHFCF_2OCH_3$	0.94	98
HFE-356pcc3	$CHF_2CF_2CF_2OCH_3$	0.93	110
HFE-356pcf2	$CHF_2CF_2OCH_2CHF_2$	2	260
HFE-365mcf3	$CF_3CF_2CH_2OCH_3$	0.11	11
$(CF_3)_2CHOCHF_2$		3.1	370
$(CF_3)_2CHOCH_3$		0.25	26
$-(CF_2)_4CH(OH)-$		0.85	70
*** Estimated lower limit based upon perfluorinated structure.**			

Annex 2. Table 2 [2, Intergovernmental Panel on Climate Change, 2001]

http://www.grida.no/climate/ipcc_tar/wg1/249.htm#tab68

ANNEX 3 - AQUATIC TOXICITY POTENTIALS

CAS number	Substance	PNEC$_{TGD}$ (mg/1)	Effect factor LCA (l/mg)	Reliability
71-55-6	1,1,1-Trichloroethane	2.1E+00	4.8E-01	A&S/QSAR
634-66-2	1,2,3,4-Tetrachlorobenzene	2.3E-02	4.3E+01	A&S/QSAR
634-90-2	1,2,3,5-Tetrachlorobenzene	2.2E-02	4.5E+01	A&S/QSAR
87-61-6	1,2,3-Trichlorobenzene	6.4E-02	1.6E+01	A&S/QSAR
95-94-3	1,2,4,5-Tetrachlorobenzene	2.6E-02	3.8E+01	A&S/QSAR
120-82-1	1,2,4-Trichlorobenzene	7.9E-02	1.3E+01	A&S/QSAR
95-50-1	1,2-Dichlorobenzene	2.7E-01	3.7E+00	A&S/QSAR
107-06-2	1,2-Dichloroethane	1.4E+01	7.1E-02	A&S/QSAR
108-70-3	1,3,5-Trichlorobenzene	5.7E-02	1.8E+01	A&S/QSAR
106-99-0	1,3-Butadiene	7.13E-02	1.40E+01	TGD/1000
541-73-1	1,3-Dichlorobenzene	2.1E-01	4.8E+00	A&S/QSAR
106-46-7	1,4-Dichlorobenzene	2.6E-01	3.8E+00	A&S/QSAR
100-00-5	1-Chloro-4-nitrobenzene	3.2E-03	3.1E+02	TGD/100
634-83-3	2,3,4,5-Tetrachloroaniline	3.2E-04	3.1E+03	TGD/100
-	2,3,4,6-Tetrachloroaniline	No data available		
58-90-2	2,3,4,6-Tetrachiorophenol	1.4E-03	7.1E+02	TGD/100*
634-93-5	2,3,4-Trichloroaniline	7.3E-03	1.4E+02	TGD/100*
3481-20-7	2,3,5,6-Tetrachloroaniline	3E-04	3E+03	TGD/1000
1746-01-6	2,3,7,8-TCDD (dioxin)	1.2E-09	8.3E+08	TGD/10
87-59-2	2,3-Dimethylaniline	1.6E-03	6.3E+02	TGD/100
93-76-5	2,4,5-T	1.6E-01	6.3E+00	TGD/100
636-30-6	2,4,5-Trichloroaniline	1.8E-02	5.6E+01	TGD/100*
95-95-4	2,4,5-Trichlorophenol	4.8E-03	2.1E+02	TGD/50
634-93-5	2,4,6-Trichloroaniline	2.3E-03	4.3E+02	TGD/1000
88-06-2	2,4,6-Trichlorophenol	1.3E-02	7.7E+01	TGD/50
2683-43-4	2,4-Dichloro-6-nitroaniline	2.1E-03	4.8E+02	TGD/1000
554-00-7	2,4-Dichloroaniline	5.0E-02	2.0E+01	A&S/n=14
120-83-2	2,4-Dichlorophenol	5.8E-03	1.7E+02	TGD/50
95-68-1	2,4-Dimethylaniline	2.5E-01	4.0E+00	A&S/n=6
97-02-9	2,4-Dinitroaniline	9.6E-03	1.0E+02	TGD/1000
94-75-7	2,4 D (2,4-dichlorophenoxyacetic acid)	9.9E-03	1.0E+02	A&S/n=19
95-82-9	2,5-Dichloroaniline	2.9E-03	3.4E+02	TGD/1000
608-31-1	2,6-Dichloroaniline	1E-03	1E+03	TGD/1000
615-65-6	2-Chloro-4-methylaniline	3.6E-02	2.8E+01	TGD/1000
1121-87-9	2-Chloro-4-nitroaniline	2.0E-02	5.0E+01	TGD/10000
95-57-8	2-Chlorophenol	3E-03	3E+02	TGD/100
95-53-4	2-Methylaniline	2.3E-01	4.3E+00	A&S/n=6
95-51-2	2-Monochloroaniline	6.4E-04	1.6E+03	TGD/50
88-74-4	2-Nitroaniline	1.9E-02	5.3E+01	TGD/1000
95-76-1	3,4-Dichloroaniline	8.0E-04	1.3E+03	A&S/n=29
95-64-7	3,4-Dimethylaniline	1.6E-04	6.3E+03	TGD/100
626-43-7	3,5-Dichloroaniline	1.1E-02	9.1E+01	TGD/100*
95-74-9	3-Chloro-4-methylaniline	8.E-03	1.E+02	TGD/50
108-44-1	3-Methylaniline	1.E-04	1.E+04	TGD/100
108-42-9	3-Monochloroaniline	1.3E-03	7.7E+02	TGD/10
99-09-2	3-Nitroaniline	1E-02	1E+02	TGD/50
106-49-0	4-Methylaniline	2E-03	5E+02	TGD/100*
106-47-8	4-Monochloroaniline	8.0E-04	1.3E+03	A&S/n=7
100-01-6	4-Nitroaniline	4.3E-01	2.3E+00	A&S/n=6
98-07-7	α,α,α-Trichlorotoluene	2.7E-02	3.7E+01	TGD/1000
98-87-3	α,α-Dichlorotoluene	No data available		
100-44-7	α-Chlorotoluene	1.3E-03	7.7E+02	TGD/1000
959-98-8	α-Endosulphan	2E-05	5E+04	TGD/10
319-84-6	α-Hexachloorcyclohexane (α-HCH)	3.5E-03	2.9E+02	A&S/n=7
30560-19-1	Acephate	6.4E-03	1.6E+02	TGD/1000

CAS number	Substance	PNEC$_{TGD}$ (mg/1)	Effect factor LCA (l/mg)	Reliability
107-02-8	Acroleine	7E-06	1E+05	TGD/1000
107-13-1	Acrylonitrile	7.6E-03	3E+02	TGD/1000
116-06-3	Aldicarb	2E-05	5E+04	TGD/50
309-00-2	Aldrin	2.9E-05	3.4E+04	A&S/n=6
-	Alkyldimethylbenzyl-ammonium	No data available		
7664-41-7	Ammonia	1.6E-03	6.3E+02	TGD/100
101-05-3	Anilazin	2E-04	6E+03	TGD/50
120-12-7	Anthracene	3.34E-05	2.99E+04	TGD/50
7440-36-0	Antimony	4.6E+00	2.2E+01	TGD/50
7440-38-2	Arsenic	2.4E-02	4.2E+01	A&S/n=17
1332-21-4	Asbestos	No data available		
1912-24-9	Atrazin	2.9E-03	3.4E+02	A&S/n=23
2642-71-9	Azinphos-ethyl	1.1E-05	9.1E+04	TGD/100*
86-50-0	Azinphos-methyl	1.2E-05	8.3E+04	A&S/n=12
319-85-7	β-hexachlorocyclohexane (β-HCH)	6.1E-03	1.6E+02	A&S/n=6
7440-39-3	Barium	5.8E-02	1.7E+01	TGD/50
17804-35-2	Benomyl	1.5E-04	6.7E+03	TGD/100*
25057-89-0	Bentazone	6.4E-02	1.6E+01	TGD/1000
71-43-2	Benzene	2.4E+00	4.2E-01	A&S/QSAR
56-55-3	Benzo(a)anthracene	1.0E-05	1.0E+05	TGD/1000
50-32-8	Benzo(a)pyrene	5E-06	2E+05	TGD/1000
205-99-2	Benzo(b)fluoranthene	2.2E-06	4.5E+05	TGD/1000
191-24-2	Benzo(ghi)perylene	3.0E-05	3.3E+04	A&S/QSAR
207-08-9	Benzo(k)fluoranthene	3.6E-06	2.8E+05	TGD/100
7440-41-7	Beryllium	1.6E-04	6.3E+03	A&S/n=7
82657-04-3	Bifenthrin	1.1E-06	9.1E+05	TGD/100*
85-68-7	Butylbenzylphtalate	7.5E-03	1.3E+02	TGD/10
7440-43-9	Cadmium	3.4E-04	2.9E+03	A&S/n=87
2425-06-1	Captafol	2.8E-05	3.6E+04	TGD/1000
133-06-2	Captan	2.2E-05	4.5E+04	TGD/50
63-25-2	Carbaryl	2.3E-04	4.3E+03	A&S/n=17
10605-21-7	Carbendazim	2E-04	5E+03	TGD/50
1563-66-2	Carbofuran	2.0E-04	5.0E+03	TGD/50
75-15-0	Carbon disulphide	2.1E-03	4.8E+02	TGD/1000
75-69-4	CFK-11 (CFCL$_3$)	No data available		
26523-64-8	CFK-113 (C$_2$F$_3$CL$_3$)	No data available		
1320-37-2	CFK-114 (C$_2$F$_4$CL$_2$)	No data available		
76-15-3	CFK-115 (C$_2$F$_5$CL)	No data available		
75-71-8	CFK-12 (CF$_2$CL$_2$)	No data available		
75-72-9	CFK-13 (CF$_3$CL)	No data available		
57-74-9	Chlordane	1.5E-06	6.7E+05	TGD/10
470-90-6	Chlorfenvinphos	3E-03	3E+02	TGD/100
1698-60-8	Chloridazon	7.3E-02	1.4E+01	TGD/10
108-90-7	Chlorobenzene	6.9E-01	1.4E+00	A&S/QSAR
1897-45-6	Chlorothalonil	8.8E-04	1.1E+03	TGD/100*
101-21-3	Chlorpropham	3.8E-02	2.6E+01	TGD/100*
2921-88-2	Chlorpyriphos	2.8E-06	3.6E+05	A&S/n=9
7440-47-3	Chrome	8.5E-03	1.2E+02	A&S/n=55
7440-47-3	Chrome(III)	3.4E-02	2.9E+01	A&S/n=7
7440-47-3	Chrome(VI)	8.5E-03	1.2E+02	A&S/n=55
218-01-9	Chrysene	3.4E-04	2.9E+03	A&S/QSAR
7440-48-4	Cobalt	2.6E-03	3.8E+02	A&S/n=8
7440-50-8	Copper	1.1E-03	9.1E+02	A&S/n=89
56-72-4	Coumaphos	7.4E-07	1.4E+06	TGD/100*
21725-46-2	Cyanazin	5E-05	2E+04	TGD/100
52315-07-8	Cypermethrin	1.3E-07	7.7E+06	TGD/50
66215-27-8	Cyromazine	4.5E-04	2.2E+03	TGD/1000
72-54-8	DDD	2.4E-05	4.2E+04	TGD/100*

CAS number	Substance	$PNEC_{TGD}$ (mg/1)	Effect factor LCA (l/mg)	Reliability
72-55-9	DDE	1E-06	1E+06	TGD/100
50-29-3	DDT	5E-06	2E+05	TGD/10
52918-63-5	Deltamethrin	3E-07	3E+06	TGD/100*
126-75-0	Demeton	1.4E-04	7.1E+03	TGD/100*
1014-69-3	Desmethryn	2.6E-02	3.8E+01	TGD/1000
117-81-7	Di(2-ethyl) hexylphthalate	2.6E-03	3.8E+02	TGD/10
333-41-5	Diazinon	3.7E-05	2.7E+04	A&S/n=11
84-74-2	Dibutylphthalate	1E-02	1E+02	TGD/10
'75-09-2	Dichloromethane	2.0E+01	5.0E-02	A&S/QSAR
120-36-5	Dichlorprop	4E-02	3E+01	TGD/10
62-73-7	Dichlorvos	7E-07	1E+06	TGD/100*
60-57-1	Dieldrin	2.9E-05	3.4E+04	A&S/n=6
84-66-2	Diethylphthalate	7.3E-02	1.4E+01	TGD/50
I84-75-3	Dihexylphthalate	8.4E-03	1.2E+02	TGD/10
26761-40-0	Diisodecylphthalate	2.9E-03	3.5E+02	TGD/50
27554-26-3	Diisooctylphthalate	1.2E-03	8.1E+02	TGD/50
60-51-5	Dimethoate	2.3E-02	4.3E+01	A&S/n=13
133-11-3	Dimethylphthalate	1.9E-01	5.2E+00	TGD/50
88-85-7	Dinoseb	2.5E-05	4.0E+04	TGD/10
1420-07-1	Dinoterb	3.4E-05	2.9E+04	TGD/100*
117-84-0	Dioctylphtalate	6.4E-03	1.6E+02	TGD/50
298-04-4	Disulphoton	2.3E-05	4.3E+04	TGD/100*
330-54-2	Diuron	4.3E-04	2.3E+03	A&S/n= 11
534-52-1	DNOC	2.1E-02	4.8E+01	A&S/n=16
72-20-8	Endrin	3E-06	3E+05	TGD/10
106-89-8	Epichlorohydrin	1.06E-02	9.43E+01	TGD/1000
-	Epoxiconazole	No data available		
66230-04-4	Esfenvalerate	2.7E-07	3.7E+06	TGD/1000
13194-48-4	Ethoprophos	6.3E-05	1.6E+04	TGD/100*
100-41-4	Ethylbenzene	3.7E-01	2.7E+00	A&S/QSAR
74-85-1	Ethylene	8.5E+00	1.2E+01	A&S/QSAR
96-45-7	ETU (ethyleenthioureum)	2.6E-01	3.8E+00	TGD/100*
122-14-5	Fenitrothion	8.7E-06	1.1E+05	TGD/10
13684-63-4	Fenmedifam	1.65E-02	6.06E+01	TGD/1000
55-38-9	Fenthion	3.1E-06	3.2E+05	A&S/n=4
206-44-0	Fluoranthene	2.4E-04	4.2E+03	TGD/50
133-07-3	Folpet	1.2E-04	8.3E+03	TGD/100*
50-00-0	Formaldehyde	2.1E-03	4.8E+02	TGD/1000
13171-21-6	Fosfamidon	5E-03	2E+02	TGD/1000
58-89-9	γ-hexachlorocyclohexane (γ-HCH, lindane)	1.0E-03	1.0E+03	A&S/n=14
1071-83-6	Glyphosate	1.6E-03	6.3E+02	TGD/1000
76-44-8	Heptachlor	8.6E-06	1.2E+05	TGD/100
1024-57-3	Heptachlor-epoxide	4E-08	3E+07	TGD/1000
23560-59-0	Heptenophos	2E-05	5E+04	TGD/100*
87-68-3	Hexachloro-1,3-butadiene	5E-06	2E+05	TGD/100
118-74-1	Hexachlorobenzene	2.4E-03	4.2E+02	A&S/QSAR
193-39-5	Indeno(1,2,3,c-d)pyrene	1.8E-05	5.6E+04	TGD/100
7439-97-6	Inorganic mercury	2.3E-04	4.3E+03	A&S/n=38
36734-19-7	Iprodione	2.3E-03	4.3E+02	TGD/1000
98-82-8	Isopropylbenzene	6E-04	2E+03	TGD/1000
34123-59-6	Isoproturon	3.2E-04	3.1E+03	TGD/10
7439-92-1	Lead	1.1E-02	9.1E+01	A&S/n =42
330-55-2	Linuron	2.5E-04	4.0E+03	TGD/10
108-38-3	M-xylene	3.3E-01	3.0E+00	A&S/QSAR
121-75-5	Malathion	1.3E-05	7.7E+04	A&S/n=15
8018-01-7	Mancozeb	4.0E-04	2.5E+03	TGD/1000
12427-38-2	Maneb	1.8E-04	5.6E+03	TGD/100

CAS number	Substance	$PNEC_{TGD}$ (mg/1)	Effect factor LCA (l/mg)	Reliability
94-74-6	MCPA (monochlorophenoxy acetic acid)	4.2E-02	2.4E+01	TGD/50
7085-19-0	Mecoprop (MCPP)	3.9E-03	2.6E+02	TGD/100*
7430-97-6	Mercury	2.4E-04	4.2E+03	A&S/n=38
41394-05-2	Metamitron	1.00E-01	1.00E+01	TGD/1000
67129-08-2	Metazachlor	3.4E-02	2.9E+01	TGD/10
18691-97-9	Methabenzthiazuron	8.4E-03	1.2E+02	TGD/1000
137-42-8	Metham-sodium	3.5E-05	2.9E+04	TGD/1000
74-82-8	Methane	No data available		
16752-77-5	Methomyl	8E-05	1E+04	TGD/100*
-	Methyl-mercury	1 E-05	1E+05	A&S/n = 11
74-83-9	Methylbromide	1.1E-02	9.1E+01	TGD/1000
3060-89-7	Metobromuron	3.6E-02	2.8E+01	TGD/1000
51218-45-2	Metolachlor	2E-04	5E+03	TGD/10
26718-65-0	Mevinfos	1.6E-06	6.3E+05	TGD/100*
8012-95-1	Minerale olie	No data available		
7439-98-7	molybdene	2.9E-02	3.4E+01	TGD/1000
121-72-2	N,N,3-trimethylaniline	5.0E-02	2.0E+01	TGD/1000
121-69-7	N,N-dimethylaniline	1.8E-04	5.6E+03	TGD/1000
100-61-8	N-methylaniline	7.6E-05	1.3E+04	TGD/1000
91-20-3	Naphthalene	4.2E-04	2.4E+03	TGD/50
7440-02-0	Nickel	1.8E-03	5.6E+02	A&S/n=15
139-13-9	NTA	1.14E-01	8.77E+00	TGD/1000
95-49-8	O-chlorotoluene	3.0E-01	3.3E+00	A&S/QSAR
95-47-6	O-xylene	4.0E-01	2.5E+00	A&S/QSAR
23135-22-0	Oxamyl	1.8E-03	5.6E+02	TGD/100*
301-12-2	Oxydemeton-methyl	3.5E-05	2.9E+04	TGD/1000
106-43-4	P-chlorotoluene	3.3E-01	3.0E+00	A&S/QSAR
106-42-3	P-xylene	3.3E-01	3.0E+00	A&S/QSAR
56-38-2	Parathion-ethyl	1.9E-06	5.3E+05	A&S/n=10
298-00-0	Parathion-methyl	1.1E-05	9.1E+04	TGD/10
37680-73-2	PCB-101	No data available		
-	PCB-118	3.8E-03	2.6E+02	A&S/QSAR
26601-64-9	PCB-138	No data available		
35065-27-1	PCB-153	2.7E-02	3.7E+01	A&S/QSAR
-	PCB-180	No data available		
7012-37-5	PCB-28	No data available		
35693-99-3	PCB-52	No data available		
527-20-8	Pentachloroaniline	1E-04	1E+04	TGD/100
608-93-5	Pentachlorobenzene	7.5E-03	1.3E+02	A&S/QSAR
82-68-8	Pentachloronitrobenzene	2.9E-04	3.4E+03	TGD/1000
87-86-5	Pentachlorophenol (PCP)	3.5E-03	2.9E+02	A&S/n=23
52645-53-1	Permethrin	3E-07	3E+06	TGD/10
85-01-8	Phenanthrene	3.2E-03	3.1E+02	TGD/10
108-95-2	Phenol	9E-04	1E+03	TGD/10
7723-14-0	Phosphate (as P)	$PNEC_{TGD}$ not Derived[14]		
14816-18-3	Phoxim	8.2E-05	1.2E+04	TGD/1000
85-44-9	Phtalic anhydride	7.8E-03	1.3E+02	TGD/1000
23103-98-2	Pirimicarb	9E-05	1E+04	TGD/10
1918-16-7	Propachlor	1.3E-03	7.7E+02	TGD/10
114-26-1	Propoxur	1E-05	1E+05	TGD/100*
75-56-9	Propylene oxide	1.70E-01	5.88E+00	TGD/1000
13457-18-6	Pyrazophos	4E-05	3E+04	TGD/100*
7782-49-2	Selenium	5.3E-03	1.9E+02	A&S/n=31

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[14] Although some toxicological data has been found, no $PNEC_{TGD}$ has been derived for phosphate since this leads to results that are not logical (an extremely high effect factor would be derived). As a consequence phosphate does not contribute to the environmental theme of aquatic toxicity, but it does still feature in the eutrophication theme.

CAS number	Substance	PNEC_{TGD} (mg/1)	Effect factor LCA (l/mg)	Reliability
122-34-9	Simazin	1.4E-04	7.1E+03	TGD/1000
100-42-5	Styrene	5.7E-01	1.8E+00	A&S/QSAR
56-35-9	TBTO (salt water)	1 E-06	1E+6	A&S/n = 15
56-35-9	TBTO (fresh water)	1.4E-05	7.1E+4	A&S/n=9
886-50-0	Terbutryn	3E-03	3E+02	TGD/1000
1461-25-2	Tetrabutyltin (salt water)	1.7E-05	5.8E+05	TGD/1000
1461-25-2	Tetrabutyltin (fresh water)	1.6E-03	6.5E+02	TGD/1000
127-18-4	Tetra chloroethylene (perchloroethylene)	3.3E-01	3.0E+00	A&S/QSAR
56-23-5	Tetrachloromethane	1.1E+00	9.1 E-01	A&S/QSAR
7440-28-0	Thallium	1.6E-03	6.3E+02	TGD/100*
137-26-8	Thiram	3.2E-05	3.1E+05	TGD/10
7440-31-5	Tin	1.8E-02	5.6E+01	TGD/10
57018-04-9	Tolclofos-methyl	7.9E-04	1.3E+03	TGD/1000
108-88-3	Toluene	7.3E-01	1.4E+00	A&S/QSAR
2303-17-5	Tri-allate	8E-05	1E+04	TGD/1000
24017-47-8	Triazophos	3.2E-05	3.1E+04	TGD/10
56-36-0	Tributyltin-acetate (salt water)	1E-06	1E+6	A&S/n = 15
56-36-0	Tributyltin-acetate (fresh water)	1.4E-05	7.1E+4	A&S/n=9
1461-22-9	Tributyltin-chloride (salt water)	1E-06	1E+6	A&S/n=15
1461-22-9	Tributyltin-chloride (fresh water)	1.4E-05	7.1E+4	A&S/n=9
52-68-6	Trichlorfon	1.E-06	1E+06	TGD/100*
79-01-6	Trichloroethylene	2.4E+00	4.2E-01	A&S/QSAR
67-66-3	Trichloromethane (chloroform)	5.9E+00	1.7E-01	A&S/QSAR
1582-09-8	Trifluralin	2.6E-05	3.8E+04	TGD/50
900-95-8	Triphenyltin-acetate (salt water)	5E-06	2E+05	TGD/100
900-95-8	Triphenyltin-acetate (salt + fresh)	5E-06	2E+05	TGD/10
639-58-7	Triphenyltin-chloride (salt water)	5E-06	2E+05	TG 100
639-58-7	Triphenyltin-chloride (salt + fresh)	5E-06	2E+05	TGD/10
379-52-2	Triphenyltin-fluoride (salt water)	5E-06	2E+05	TGD/100
379-52-2	Triphenyltin-fluoride (salt + fresh)	5E-06	2E+05	TGD/10
76-87-9	Triphenyltin-hydroxide (salt water)	5E-06	2E+05	TGD/100
76-87-9	Triphenyltin-hydroxide (salt + fresh)	5E-06	2E+05	TGD/10
7440-62-2	Vanadium	8.2E-04	1.2E+03	TGD/50
75-01-4	Vinylchloride	8.2E+00	1.2&01	A&S/QSAR
7440-66-6	Zinc	6.6E-03	1.5E+02	A&S/n=49
2122-67-7	Zineb	2.0E-04	5.0E+03	TGD/50

TGD = Technical Guidance Documents, the number relates to the assessment factor used (see below)
A&S = Aldenberg & Slob method
QSAR = Quantitative Structure Activity Relationship

Annex 3. Table 1 [21, Balk, et al., 1999]

Note that the values presented in the above table have been derived using different methodologies and this makes it difficult to make comparisons between the effects of different pollutants (a short summary of the derivation method is given on the following page). At the time of writing this document, QSAR values were being derived for a variety of new and existing chemicals. Information on values that become available in the future should be available from the websites below.

http://ecb.jrc.it/new-chemicals/

http://ecb.jrc.it/existing-chemicals/

Derivation of aquatic toxicity effects

The following section is a summary of the methodologies used to derive the aquatic toxicity figures in the above table. Both the table and this text are taken from 'Effect factors for the aquatic environment in the framework of LCA' [21, Balk, et al., 1999].

The technical guidance documents (TGD)

The TGD are guidance documents that support the risk assessment legislation for new substances (EC, 1993) and existing substances (EC, 1994) within the European Community. The TGD method is designed to protect the aquatic environment. The TGD method includes both the application of assessment factors and the application of a statistical extrapolation method in case sufficient reliable data are not available. In this section, the TGD assessment factors are discussed.

The application of the assessment factors presented in the TGD is rather complicated. Performing the derivation of PNECs in the framework of LCA using the assessment factors should, therefore, be carried out by a scientist who has experience in risk assessment. An abstract of the TGD method using assessment factors is presented below. For the full version of the aquatic risk assessment, reference is made to the TGD (EC, 1993).

Information available	Assessment factor
At least one short-term $L(E)C_{50}$ from each of three trophic levels of the base-set (fish, Daphnia and algae)	1000 (a)
One long-term NOEC (either fish or Daphnia)	100 (b)
Two long-term NOECs from species representing two trophic levels (fish and/or Daphnia and/or algae)	50 (c)
Long-term NOECs for at least three species (normally fish, Daphnia and algae) representing three trophic levels	10 (d)
Field data or model ecosystems	Reviewed on a case-by-case basis (e)

Notes:

(a) An assessment factor of 1000 will be applied on the lowest $L(E)C_{50}$ available in the data set (fish, algae and Daphnia), irrespective of whether the species tested is a standard organism.

(b) An assessment factor of 100 applies to a single long-term NOEC (fish or Daphnia) (no observable effect concentration) if this NOEC was generated for the trophic level showing the lowest $L(E)C_{50}$ in the short-term tests. An assessment factor of 100 applies also to the lowest of two long-term NOECs covering two trophic levels when such NOECs have not been generated from that showing the lowest $L(E)C_{50}$ of the short-term tests.

(c) An assessment factor of 50 applies to the lowest of two NOECs covering two trophic levels when such NOECs have been generated covering that level showing the lowest $L(E)C_{50}$ in the short-term tests. It also applies to the lowest of three NOECs covering three trophic levels when such NOECs have not been generated from that level showing the lowest $L(E)C_{50}$ in the short-term tests.

(d) An assessment factor of 10 will normally only be applied when long-term aquatic toxicity NOECs are available from at least three species across three trophic levels (e.g. fish, Daphnia, and algae or a non-standard organism instead of a standard organism).

(e) The extrapolation factor may be lowered when field data or model ecosystem studies of good quality are available.

Annex 3, Table 2: Assessment factors to derive a PNEC according to the TGD

ANNEX 4 - ACIDIFICATION POTENTIALS

Substance	CAS number	Acidification potential in kg SO_2 equivalent
Ammonia	7664-41-7	1.6
Nitrogen oxides (as NO_2)	10102-44-0	0.5

Annex 4. Table 1
[15, Guinée, 2001].

These figures are derived for Switzerland. [15, Guinée, 2001].

When totalling the acidification potential, SO_2 is added with an equivalence of 1.

ANNEX 5 - EUTROPHICATION POTENTIALS

Generic eutrophication potential factors for characterising eutrophication releases to air, water and soil.

Substance	CAS number	Eutrophication potential (in kg PO_4^{3-} eq./kg)
Ammonia	7664-41-7	0.35
Ammonium	14798-03-9	0.33
Nitrate	14797-55-8	0.1
Nitric acid	7697-07-2	0.1
Nitrogen	7727-07-9	0.42
Nitrogen dioxide	10102-44-0	0.13
Nitrogen monoxide	10102-43-9	0.2
Nitrogen oxides	10102-44-0	0.13
Phosphate	7664-38-2	1
Phosphoric acid (H_3PO_4)	7664-38-2	0.97
Phosphorus (P)	7723-14-0	3.06
Phosphorus (V) oxide (P_2O_5)	1314-56-3	1.34

Annex 5. Table 1
[15, Guinée, 2001] **based on Heijungs et al., 1992 with some modifications**

ANNEX 6 - OZONE DEPLETION POTENTIALS

The following tables give ozone depleting potentials, and are taken from the Montreal Protocol [31, United Nations Environment Programme, 1987].

From Annex A: Controlled substances

Group	Substance	Ozone-depleting potential*
Group I		
$CFCl_3$	(CFC-11)	1.0
CF_2Cl_2	(CFC-12)	1.0
$C_2F_3Cl_3$	(CFC-113)	0.8
$C_2F_4Cl_2$	(CFC-114)	1.0
C_2F_5Cl	(CFC-115)	0.6
Group II		
CF_2BrCl	(halon-1211)	3.0
CF_3Br	(halon-1301)	10.0
$C_2F_4Br_2$	(halon-2402)	6.0
* **These ozone depleting potentials are estimates based on existing knowledge and will be reviewed and revised periodically.**		

Annex 6. Table 1.

From Annex B: Controlled substances

Group	Substance	Ozone-depleting potential
Group I		
CF_3Cl	(CFC-13)	1.0
C_2FCl_5	(CFC-111)	1.0
$C_2F_2Cl_4$	(CFC-112)	1.0
C_3FCl_7	(CFC-211)	1.0
$C_3F_2Cl_6$	(CFC-212)	1.0
$C_3F_3Cl_5$	(CFC-213)	1.0
$C_3F_4Cl_4$	(CFC-214)	1.0
$C_3F_5Cl_3$	(CFC-215)	1.0
$C_3F_6Cl_2$	(CFC-216)	1.0
C_3F_7Cl	(CFC-217)	1.0
Group II		
CCl_4	carbon tetrachloride	1.1
Group III		
$C_2H_3Cl_3$*	1,1,1-trichloroethane* (methyl chloroform)	0.1
* **This formula does not refer to 1,1,2-trichloroethane.**		

Annex 6. Table 2.

From Annex C: Controlled substances

Group	Substance	Number of isomers	Ozone-depleting potential*
Group I			
$CHFCl_2$	(HCFC-21)**	1	0.04
CHF_2Cl	(HCFC-22)**	1	0.055
CH_2FCl	(HCFC-31)	1	0.02
C_2HFCl_4	(HCFC-121)	2	0.01 - 0.04
$C_2HF_2Cl_3$	(HCFC-122)	3	0.02 - 0.08
$C_2HF_3Cl_2$	(HCFC-123)	3	0.02 - 0.06
$CHCl_2CF_3$	(HCFC-123)**	-	0.02
C_2HF_4Cl	(HCFC-124)	2	0.02 - 0.04
$CHFClCF_3$	(HCFC-124)**	-	0.022
$C_2H_2FCl_3$	(HCFC-131)	3	0.007 - 0.05
$C_2H_2F_2Cl_2$	(HCFC-132)	4	0.008 - 0.05
$C_2H_2F_3Cl$	(HCFC-133)	3	0.02 - 0.06
$C_2H_3FCl_2$	(HCFC-141)	3	0.005 - 0.07
CH_3CFCl_2	(HCFC-141b)**	-	0.11
$C_2H_3F_2Cl$	(HCFC-142)	3	0.008 - 0.07
CH_3CF_2Cl	(HCFC-142b)**	-	0.065
C_2H_4FCl	(HCFC-151)	2	0.003 - 0.005
C_3HFCl_6	(HCFC-221)	5	0.015 - 0.07
$C_3HF_2Cl_5$	(HCFC-222)	9	0.01 - 0.09
$C_3HF_3Cl_4$	(HCFC-223)	12	0.01 - 0.08
$C_3HF_4Cl_3$	(HCFC-224)	12	0.01 - 0.09
$C_3HF_5Cl_2$	(HCFC-225)	9	0.02 - 0.07
$CF_3CF_2CHCl_2$	(HCFC-225ca)**	-	0.025
CF_2ClCF_2CHClF	(HCFC-225cb)**	-	0.033
C_3HF_6Cl	(HCFC-226)	5	0.02 - 0.10
$C_3H_2FCl_5$	(HCFC-231)	9	0.05 - 0.09
$C_3H_2F_2Cl_4$	(HCFC-232)	16	0.008 - 0.10
$C_3H_2F_3Cl_3$	(HCFC-233)	18	0.007 - 0.23
$C_3H_2F_4Cl_2$	(HCFC-234)	16	0.01 - 0.28
$C_3H_2F_5Cl$	(HCFC-235)	9	0.03 - 0.52
$C_3H_3FCl_4$	(HCFC-241)	12	0.004 - 0.09
$C_3H_3F_2Cl_3$	(HCFC-242)	18	0.005 - 0.13
$C_3H_3F_3Cl_2$	(HCFC-243)	18	0.007 - 0.12
$C_3H_3F_4Cl$	(HCFC-244)	12	0.009 - 0.14
$C_3H_4FCl_3$	(HCFC-251)	12	0.001 - 0.01
$C_3H_4F_2Cl_2$	(HCFC-252)	16	0.005 - 0.04
$C_3H_4F_3Cl$	(HCFC-253)	12	0.003 - 0.03
$C_3H_5FCl_2$	(HCFC-261)	9	0.002 - 0.02
$C_3H_5F_2Cl$	(HCFC-262)	9	0.002 - 0.02
C_3H_6FCl	(HCFC-271)	5	0.001 - 0.03
Group II			
$CHFBr_2$		1	1.00
CHF_2Br	(HBFC-22B1)	1	0.74
CH_2FBr		1	0.73
C_2HFBr_4		2	0.3 - 0.8
$C_2HF_2Br_3$		3	0.5 - 1.8
$C_2HF_3Br_2$		3	0.4 - 1.6
C_2HF_4Br		2	0.7 - 1.2
$C_2H_2FBr_3$		3	0.1 - 1.1
$C_2H_2F_2Br_2$		4	0.2 - 1.5
$C_2H_2F_3Br$		3	0.7 - 1.6
$C_2H_3FBr_2$		3	0.1 - 1.7
$C_2H_3F_2Br$		3	0.2 - 1.1
C_2H_4FBr		2	0.07 - 0.1

Group	Substance	Number of isomers	Ozone-depleting potential*
C_3HFBr_6		5	0.3 - 1.5
$C_3HF_2Br_5$		9	0.2 - 1.9
$C_3HF_3Br_4$		12	0.3 - 1.8
$C_3HF_4Br_3$		12	0.5 - 2.2
$C_3HF_5Br_2$		9	0.9 - 2.0
C_3HF_6Br		5	0.7 - 3.3
$C_3H_2FBr_5$		9	0.1 - 1.9
$C_3H_2F_2Br_4$		16	0.2 - 2.1
$C_3H_2F_3Br_3$		18	0.2 - 5.6
$C_3H_2F_4Br_2$		16	0.3 - 7.5
$C_3H_2F_5Br$		8	0.9 - 1.4
$C_3H_3FBr_4$		12	0.08 - 1.9
$C_3H_3F_2Br_3$		18	0.1 - 3.1
$C_3H_3F_3Br_2$		18	0.1 - 2.5
$C_3H_3F_4Br$		12	0.3 - 4.4
$C_3H_4FBr_3$		12	0.03 - 0.3
$C_3H_4F_2Br_2$		16	0.1 - 1.0
$C_3H_4F_3Br$		12	0.07 - 0.8
$C_3H_5FBr_2$		9	0.04 - 0.4
$C_3H_5F_2Br$		9	0.07 - 0.8
C_3H_6FBr		5	0.02 - 0.7
Group III			
CH_2BrCl	Bromochloromethane***	1	0.12

* Where a range of ODPs is indicated, the highest value in that range shall be used for the purposes of the Protocol. The ODPs listed as a single value have been determined from calculations based on laboratory measurements. Those listed as a range are based on estimates and are less certain. The range pertains to an isomeric group. The upper value is the estimate of the ODP of the isomer with the highest ODP, and the lower value is the estimate of the ODP of the isomer with the lowest ODP.

** Identifies the most commercially viable substances with ODP values listed against them to be used for the purposes of the Protocol.

*** From the Beijing Amendment.

Annex 6. Table 3.

From Annex E: Controlled substance

Group	Substance	Ozone-depleting potential
Group I		
CH_3Br	Methyl bromide	0.6

Annex 6. Table 4
(for all of the Ozone Depletion Tables): [31, United Nations Environment Programme, 1987]

http://www.unep.org/ozone/pdf/Montreal-Protocol2000.pdf

http://www.unep.org/ozone/Beijing-Amendment.shtml

http://www.unep.org/ozone/mont_t.shtml#annex_a

ANNEX 7 - PHOTOCHEMICAL OZONE CREATION POTENTIALS

Hydrocarbon		Photochemical ozone creation potential
Alkanes		
Methane		0.006
Ethane		0.123
Propane		0.176
n-butane		0.352
i-butane		0.307
n-pentane		0.395
i-pentane		0.405
Neopentane		0.173
n-hexane		0.482
2-methylpentane		0.42
3-methylpentane		0.479
2,2-dimethylbutane		0.241
2,3-dimethylbutane		0.541
n-heptane		0.494
2-methylhexane		0.411
3-methylhexane		0.364
n-octane		0.453
n-nonane		0.414
2-methyloctane*		0.7061
n-decane		0.384
2-methylnonane*		0.6571
n-undecane		0.384
n-dodecane		0.357
Cyclohexane		0.29
Cyclohexanone		0.299
Cyclohexanol**		0.5182
Alkenes		
Ethylene		1
Propylene		1.123
but -1- ene		1.079
cis -but -2 – ene		1.146
trans - but - 2 - ene		1.132
methylpropene		0.627
cis - pent - 2 – ene		1.121
trans – pent - 2 - ene		1.117
pent - 1 – ene		0.977
2-methylbut-1-ene		0.771
3-methylbut-1-ene		0.671
2-methylbut-2-ene		0.842
hex - 1- ene		0.874
cis - hex -2- ene		1.069
trans - hex -2- ene		1.073
Styrene		0.142
1, 3 - butadiene		0.851
Isoprene		1.092
Alkynes		
Acetylene		0.085
Aromatics		
Benzene		0.218
Toluene		0.637
o-xylene		1.053
m-xylene		1.108

Hydrocarbon		Photochemical ozone creation potential
p-xylene		1.01
Ethylbenzene		0.73
n-propylbenzene		0.636
i-propylbenzene		0.5
1,2,3-trimethylbenzene		1.267
1,2,4-trimethylbenzene		1.278
1,3,5-trimethylbenzene		1.381
o-ethyltoluene		0.898
m-ethyltoluene		1.019
p-ethyltoluene		0.906
3,5-dimethylethylbenzene		1.32
3,5-diethyltoluene		1.295
Aldehydes		
Formaldehyde		0.519
Acetaldehyde		0.641
Propionaldehyde		0.798
Butyraldehyde		0.795
i-butyraldehyde		0.514
Pentanaldehyde		0.765
Benzaldehyde		-0.092
Ketones		
Acetone		0.094
Methylethylketone		0.373
Methyl-i-butylketone		0.49
Methylpropylketone		0.548
Diethylketone		0.414
Methyl - i – propylketone		0.364
Hexan -2- one		0.572
Hexan -3- one		0.599
Methyl -t- butylketone		0.323
Alcohols		
Methanol**		0.1402
Ethanol**		0.3992
1-propanol**		0.5612
2-propanol**		0.1882
1-butanol**		0.6202
2-butanol**		0.4472
2-methyl-1-propanol**		0.3602
2-methyl-2-propanol**		0.1062
3-pentanol**		0.5952
2-methyl-1-butanol**		0.4892
3-methyl-1-butanol**		0.4332
2-methyl-2-butanol**		0.2282
3-methyl-2-butanol**		0.4062
Diacetone alcohol		0.262
4-hydroxy-4-methyl-2-pentanone**		0.3072
Diols		
Ethane-1,2-diol**		0.3732
Propane-1,2-diol**		0.4572
Ethers		
Dimethyl ether**		0.1892
Diethyl ether**		0.4452
Methyl-t-butyl-ether**		0.1752

Hydrocarbon		Photochemical ozone creation potential
Di-i-propyl ether**		0.3982
Ethyl-t-butyl ether**		0.2422
Glycol ethers		
2-methoxy ethanol**		0.3072
2-ethoxy ethanol**		0.3862
1-methoxy-2-propanol**		0.3552
2-butoxy ethanol**		0.4832
1-butoxy-2-propanol**		0.4632
Esters		
Methyl formate**		0.0272
Methyl acetate**		0.0592
Ethyl acetate**		0.2092
n-propyl acetate**		0.2822
i-propyl acetate**		0.2112
n-butyl acetate**		0.2692
s-butyl acetate**		0.2752
t-butyl acetate**		0.0532
Organic acids		
Formic acids		0.032
Acetic acid		0.097
Propionic acid		0.15
New oxygenates		
Dimethoxy methane**		0.1642
Dimethyl carbonate**		0.0252
Halocarbons		
Chloromethane		0.005
Methylene chloride		0.068
Chloroform		0.017
Methylchloroform		0.009
Tetrachloroethylene		0.029
Trichloroethylene		0.325
Vinyl chloride*		0.2721
1,1-dichloroethane*		0.2321
Cis –dichloroethylene		0.447
Trans –dichloroethylene		0.392
Other pollutants		
Nitric oxide		*** -0.46 to 4.09
Nitrogen dioxide		*** -0.06 to 3.8
Sulphur dioxide		0.048
Carbon monoxide		0.027
*** Derwent et al (ref 27) from H1.** **** Jenkin and Hayman (ref 28) from H1.** ***** Ranges given reflect the important but variable role of these substance groups in ozone formation.**		

Annex 7. Table 1.
[18, UK Environment Agencies, 2002]

ANNEX 8 - EUROPEAN ENERGY MIX

Electricity

To create 1 GJ of electricity, the average fuel use and emissions released for the whole of Europe is:

Electricity	**GJ**	**1**
Primary energy	**GJ**	**2.57**
Oil	**kg**	**9.01**
Gas	**m^3**	**6.92**
Coal	**kg**	**15.7**
Brown coal	**kg**	**34.6**
SO_2	**kg**	**0.10**
CO_2	**kg**	**117**
NO_2	**kg**	**0.16**

European Mix	
Oil	9.6 %
Gas	9.5 %
Hard coal	18.3 %
Brown coal	10.5 %
Nuclear	36.0 %

IFEU-Calculation		**Fuel oil**	**Electricity from oil firing**	**Natural gas**	**Electricity from gas**	**Hard coal**	**Electricity from coal**	**Brown coal**	**Electricity from brown coal**	**Nuclear power**
Current	GJ		1.00E+00		1.00E+00		1.00E+00		1.00E+00	1.00E+00
Primary energy	GJ	3.69E+00		2.90E+00		2.38E+00		2.82E+00		3.35E+00
Oil	kg	9.22E+01	7.88E+01							4.19E-01
Gas	m^3			7.14E+01	5.33E+01					3.74E-01
Coal	kg					8.48E+01	8.19E+01			3.03E+00
Brown coal	kg							3.19E+02	3.12E+02	
SO_2	kg	6.44E-02	2.43E-01	3.24E-03	2.88E-03	5.05E-02	1.48E-01	3.73E-03	2.22E-01	3.22E-02
CO_2	kg	1.26E+01	2.47E+02	1.46E+01	1.32E+02	1.06E+01	2.17E+02	7.84E+00	3.16E+02	6.27E+00
NO_2	kg	3.46E-02	3.68E-01	7.79E-02	1.51E-01	4.11E-02	1.10E-01	6.30E-03	6.14E-01	1.43E-02

Annex 8. Table 1.
[33, Fehrenbach H, 2002].

These average emission factors for electricity are derived from the ECOINVENT 1994 database.

Steam

To produce steam with energy value of 1 GJ, the average fuel use and emissions released for the whole of Europe is:

Steam	**GJ**	**1**
Primary energy	**GJ**	**1.32**
Oil	**kg**	**12.96**
Gas	**m^3**	**10.46**
Coal	**kg**	**14.22**
SO_2	**kg**	**0.54**
CO_2	**kg**	**97.20**
NO_2	**kg**	**0.18**

European Mix	
(estimated mix)	
Oil	40.0 %
Gas	30.0 %
Hard Coal	30.0 %

		Fuel oil	**Heat from oil firing**	**Natural gas**	**Heat from gas**	**Hard coal**	**Heat from coal**
Heat	GJ		1.00E+00		1.00E+00		1.00E+00
Primary energy	GJ	1.29E+00		1.41E+00		1.28E+00	
Oil	kg	3.24E+01	2.75E+01				
Gas	m^3			3.49E+01	2.81E+01		
Coal	kg					4.74E+01	4.14E+01
SO_2	kg	4.01E-02	9.95E-01	1.61E-02	5.75E-04	4.76E-02	3.70E-01
CO_2	kg	6.51E+00	9.22E+01	7.16E+00	6.48E+01	5.82E+00	1.15E+02
NO_2	kg	1.77E-02	1.78E-01	3.47E-02	4.47E-02	3.77E-02	2.17E-01
ECOINVENT		**Fuel oil**	**Heat from oil firing**	**Natural gas**	**Heat from gas**	**Hard coal**	**Heat from coal**
Heat	GJ		1.00E+00		1.00E+00		1.00E+00
Primary Energy	GJ	1.22E+00		1.43E+00		1.36E+00	
Oil	kg	3.06E+01	2.60E+01				
Gas	m^3			3.53E+01	3.00E+01		
Coal	kg					5.21E+01	4.17E+01
SO_2	kg	1.59E-02	1.41E+00	3.06E-02	6.47E-04	6.98E-02	6.29E-01
CO_2	kg	4.24E-01	9.16E+01	7.29E+00	6.47E+01	6.36E+00	1.16E+02
NO_2	kg	8.24E-04	1.88E-01	3.18E-02	2.35E-02	5.50E-02	2.50E-01
GEMIS		**Fuel oil**	**Heat from oil firing**	**Natural gas**	**Heat from gas**	**Hard coal**	**Heat from coal**
Heat	GJ		1.00E+00		1.00E+00		1.00E+00
Primary Energy	GJ	1.35E+00		1.39E+00		1.20E+00	
Oil	kg	3.42E+01	2.89E+01				
Gas	m^3			3.44E+01	2.63E+01		
Coal	kg					4.27E+01	4.12E+01
SO_2	kg	6.44E-02	5.78E-01	1.52E-03	5.03E-04	2.54E-02	1.11E-01
CO_2	kg	1.26E+01	9.27E+01	7.02E+00	6.49E+01	5.28E+00	1.13E+02
NO_2	kg	3.46E-02	1.69E-01	3.76E-02	6.59E-02	2.05E-02	1.83E-01

Annex 8. Table 2.
Source: [33, Fehrenbach H, 2002]

These average emissions factors for steam generation are derived as averages from the ECOINVENT and GEMIS databases.

ANNEX 9 - COUNCIL DIRECTIVE (85/337/EEC)

COUNCIL DIRECTIVE (85/337/EEC)
On the assessment of the effects of certain public and private projects on the environment

ANNEX III
INFORMATION REFERRED TO IN ARTICLE 5 (1)

1. Description of the project including in particular:
    - a description of the physical characteristics of the whole project and the land-use requirements during the construction and operational phases
    - a description of the main characteristics of the production processes, for instance nature and quantity of the materials used
    - an estimate by type and quantity of expected residues and emissions (water, air and soil, pollution, noise, vibration, light, heat radiation, etc.) resulting from the operation of the proposed project.

2. Where appropriate an outline of the main alternatives studied by the developer and an indication of the main reasons for his choice taking into account the environmental effects.

3. A description of the aspects of the environment likely to be significantly affected by the proposed project, including in particular population, fauna, flora, soil, water, air, climatic factors, material assets including the architectural and archaeological heritage, landscape and the inter-relationship between the above factors.

4. A description (this description should cover the direct effects and any indirect secondary cumulative short medium and long-term permanent and temporary positive and negative effects of the project) of the likely significant effects of the proposed project on the environment resulting from:
    - the existence of the project
    - the use of natural resources
    - the emission of pollutants the creation of nuisances, and the elimination of waste; and the description by the developer of the forecasting methods used to assess the effects on the environment.

5. A description of the measures envisaged to prevent, reduce, and where possible offset any significant adverse effects on the environment.

6. A non-technical summary of the information provided under the above headings.

7. An indication of any difficulties (technical deficiencies or lack of know-how) encountered by the developer in compiling the required information.

ANNEX 10 - EUROPEAN PRICE INDICES

The most comprehensive source of relevant price indices for the EU is Eurostat's 'Data for short-term economic analysis' which is a monthly publication. The data in these publications are abstracted from their on-line database: New Cronos. The following indices are available:

1) Industrial Producer Price Index:

- a) total industry (nominal)
- b) manufacturing (by sector; nominal)
- c) capital goods (nominal)
- d) construction (nominal)
- e) hourly wages in industry (nominal and real)

2) Producer Price Index of Agricultural Products

3) Purchase Price Index of Agricultural Products

4) Implicit Deflator of GDP (in EUR and national currencies)

5) Change in Implicit Deflator of GDP (in EUR and national currencies)

6) Consumer Price Index:

- a) CPI in EUR in EU countries (by good/service)
- b) Yearly CPI in EUR
- c) Yearly growth rates of CPI in EUR

7) Exchange Rates:

- a) Yearly average exchange rate of the EUR
- b) End of year exchange rate of the EUR
- c) Monthly average exchange rate of the EUR
- d) Index of EUR exchange rates

Enquiries regarding the purchase of data should be directed to:

Eurostat Data-shop
4 rue Alphonse Weicker
L-2014 Luxembourg
Tel: +352 4335 2251
Fax: +352 4335 22221

Eurostat's home page on the Internet is (http://europa.eu.int/comm/eurostat/).

ANNEX 11 - FINANCIAL RATIOS

The following financial ratios can be useful in describing the resilience of a sector [43, Vercaemst, 2003] (see Section 5.4.1).

Liquidity

The liquidity describes the ability of an operator to pay off its immediate liabilities and can be measured using the current ratios and/or the quick ratio.

$$\text{Current ratio} = \frac{\text{Current assets}}{\text{Current liabilities}}$$

Current assets**:** are defined as those assets that are easily converted into cash (e.g. bonds, funds, accounts receivable, etc.); items such as equipment are not sold off so easily and are classified as long-term or noncurrent assets.

Current liabilities**:** are those that have to be paid within 12 months, (e.g. accounts payable to suppliers, wages, taxes, etc.).

$$\text{Quick ratio} = \frac{\text{Current assets (excluding stock)}}{\text{Current liabilities}}$$

The ‘current ratio’ and ‘quick ratio’ are similar, but because stock can sometimes be difficult to liquidate (cash, reserves, accounts receivable and bonds are easier to liquidate), the quick ratio excludes the stock.

Solvency

The ability of an operator to fulfil its obligations in the long term.

$$\text{Solvency} = \frac{\text{Equity capital}}{\text{Total liabilities}}$$

Equity capital**:** the total value of the assets of the company (i.e. the capital that could be raised by selling everything off).

Total liabilities**:** debts and outstanding financial obligations that the company has.

The higher the solvency, the less risk will be perceived by investors and the healthier the company will appear.

$$\text{Interest coverage} = \frac{\text{Operating profit}}{\text{Financial costs}}$$

Operating profit**:** a measure of the company’s earning power from ongoing operations. It is the company’s earnings before deduction of interest payments and taxes.

Financial costs**:** outgoing funds to cover loans and interest payments, or the cost of borrowing.

Interest coverage is another useful measure of solvency. The higher the interest coverage, then the healthier the company looks. Healthier companies are more able to fund environmental investments.

Profitability

If profit margins are high, the sector can be considered to be resilient and operators are in a better position to absorb the costs of implementing BAT.

$$\text{Gross profit margin} = \frac{\text{Gross profit x } 100}{\text{Sales}}$$

Gross profit**:** sometimes called ‘gross income’ is the value of the pre-tax net sales minus the cost of the goods and services sold.

Sales**:** revenue from sales.

The gross profit margin is a measure of the margin achieved on the manufacturing process. It is a guide to how much more a product can be sold for compared to what it costs to make. It can be useful for determining trends in the sector (declining gross profit margins suggest that the sector is under pressure).

$$\text{Net profit margin} = \frac{\text{Net profit before interest and taxation x } 100}{\text{Sales}}$$

Net profit before interest and taxation**:** made up from income (gross sales) minus depreciation and other expenses incurred in running the business (e.g. operating costs, heating, lighting, telephones, insurance, etc.).

This ratio is often regarded as the most appropriate measure of operational performance when making comparisons because the particular way that the company is financed will not influence the ratio.

$$\text{Return on capital employed (ROCE)} = \frac{\text{Net profit before interest and taxation x } 100}{\text{Share price + reserves + long term loans}}$$

Return on capital employed expresses the relationship between the net profit generated by the company and the long-term capital invested in the company. It is a measure of the effectiveness with which the funds have been deployed and if this ratio is greater than the cost of capital for this company, then it is a good indicator that the business is viable in the long term.

$$\text{Return on assets (ROA)} = \frac{\text{Net profit before interest and taxation x } 100}{\text{Total assets}}$$

This ratio reveals how much income the company has been able to squeeze from its assets.

ANNEX 12 - EXTERNAL COSTS FOR SOME AIR POLLUTANTS

The following results are taken from the Cost-Benefit Analysis of Air Quality Related Issues, carried out in particular in the Clean Air for Europe (CAFE) Programme (CAFE CBA), see http://europa.eu.int/comm/environment/air/cafe/activities/cba.htm. They are subject to future review and update.

The report from which they are taken notes that in interpreting the data it is essential to remember that a number of effects are excluded from quantification, including impacts on ecosystems and cultural heritage. The full set of uncertainties, including also model assumptions and statistical uncertainties may push the results either way, up or down.

Glossary of terms used in these tables – see full report for further details.

- VOLY and VSL: Valuation of mortality using the value of statistical life (VSL) and value of a life year (VOLY) approaches.
- SOMO 0 Sum of Means Over 0 ppbV
- SOMO 35 Sum of Means Over 35 ppbV

Ammonia – values in EUR/t

PM mortality	**VOLY - median**	**VSL - median**	**VOLY - mean**	**VSL - mean**
O_3 mortality	**VOLY - median**	**VOLY - median**	**VOLY - mean**	**VOLY - mean**
Health core?	**Yes**	**Yes**	**Yes**	**Yes**
Health sensitivity?	**No**	**No**	**Yes**	**Yes**
Crops	**Yes**	**Yes**	**Yes**	**Yes**
O_3/health metric	**SOMO 35**	**SOMO 35**	**SOMO 0**	**SOMO 0**
Austria	12000	19000	24000	35000
Belgium	30000	47000	60000	87000
Cyprus	-	-	-	-
Czech Republic	20000	31000	39000	57000
Denmark	7900	12000	16000	23000
Estonia	2800	4300	5600	8100
Finland	2200	3400	4300	6300
France	12000	18000	23000	34000
Germany	18000	27000	35000	51000
Greece	3200	4900	6300	9100
Hungary	11000	17000	22000	32000
Ireland	2600	4000	5100	7400
Italy	11000	17000	22000	32000
Latvia	3100	4700	6000	8800
Lithuania	1700	2700	3400	5000
Luxembourg	25000	39000	50000	72000
Malta	8200	13000	16000	24000
Netherlands	22000	34000	44000	64000
Poland	10000	15000	20000	29000
Portugal	3700	5800	7400	11000
Slovakia	14000	22000	28000	41000
Slovenia	13000	20000	25000	37000
Spain	4300	6700	8600	13000
Sweden	5900	9000	12000	17000
United Kingdom	17000	27000	34000	50000

Annex 12, Table 1: Marginal NH_3 damage in EUR per tonne emission for 2010, with three sets of sensitivity analysis.

NO_X – values in EUR/t

PM mortality **O_3 mortality** **Health core?** **Health sensitivity?** **Crops** **O_3/health metric**	**VOLY - median** **VOLY - median** **Yes** **No** **Yes** **SOMO 35**	**VSL - median** **VOLY - median** **Yes** **No** **Yes** **SOMO 35**	**VOLY - mean** **VOLY - mean** **Yes** **Yes** **Yes** **SOMO 0**	**VSL – mean** **VOLY – mean** **Yes** **Yes** **Yes** **SOMO 0**
Austria	8700	13100	16000	24000
Belgium	5200	8200	9100	14000
Cyprus	-	-	-	-
Czech Republic	7300	11000	13700	20000
Denmark	4400	6700	8300	12100
Estonia	810	1100	1600	2200
Finland	750	1100	1500	2000
France	7700	12000	14000	21000
Germany	9600	15000	18000	26000
Greece	840	1100	1400	1900
Hungary	5400	8100	10000	15000
Ireland	3800	5600	7500	11000
Italy	5700	8600	11000	16000
Latvia	1400	1900	2700	3700
Lithuania	1800	2700	3700	5000
Luxembourg	8700	13000	16000	24000
Malta	670	930	1300	1700
Netherlands	6600	10000	12000	18000
Poland	3900	5800	7100	10000
Portugal	1300	1900	2200	3200
Slovakia	5200	7800	9700	14000
Slovenia	6700	10000	13000	18000
Spain	2600	3800	5200	7200
Sweden	2200	3200	4100	5900
United Kingdom	3900	6000	6700	10000
Baltic Sea	2600	4000	4900	7200
Mediterranean Sea	530	760	990	1400
North East Atlantic	1600	2400	3500	4800
North Sea	5100	7900	9500	14000

Annex 12, Table 2: Marginal NO_X damage in EUR per tonne emission for 2010 with three sets of sensitivity analysis.

$PM_{2.5}$ – values in EUR/t

PM mortality **O_3 mortality** **Health core?** **Health sensitivity?** **Crops** **O_3/health metric**	**VOLY - median** **VOLY - median** **Yes** **No** **Yes** **SOMO 35**	**VSL - median** **VOLY - median** **Yes** **No** **Yes** **SOMO 35**	**VOLY - mean** **VOLY - mean** **Yes** **Yes** **Yes** **SOMO 0**	**VSL - mean** **VOLY - mean** **Yes** **Yes** **Yes** **SOMO 0**
Austria	37000	56000	72000	110000
Belgium	61000	94000	120000	180000
Cyprus	-	-	-	-
Czech Republic	32000	49000	62000	91000
Denmark	16000	25000	33000	48000
Estonia	4200	6500	8300	12000
Finland	5400	8300	11000	16000
France	44000	68000	87000	130000
Germany	48000	74000	95000	140000
Greece	8600	13000	17000	25000
Hungary	25000	39000	50000	72000
Ireland	15000	22000	29000	42000
Italy	34000	52000	66000	97000
Latvia	8800	14000	17000	25000
Lithuania	8400	13000	17000	24000
Luxembourg	41000	63000	81000	120000
Malta	9300	14000	18000	27000
Netherlands	63000	96000	120000	180000
Poland	29000	44000	57000	83000
Portugal	22000	34000	44000	64000
Slovakia	20000	31000	40000	58000
Slovenia	22000	34000	44000	64000
Spain	19000	29000	37000	54000
Sweden	12000	18000	23000	34000
United Kingdom	37000	57000	73000	110000
Baltic Sea	12000	19000	24000	35000
Mediterranean Sea	5600	8700	11000	16000
North East Atlantic	4800	7400	9400	14000
North Sea	28000	42000	54000	80000

Annex 12, Table 3: Marginal $PM_{2.5}$ damage in EUR per tonne emission for 2010 with three sets of sensitivity analysis.

SO_2 – values in EUR/t

PM mortality	**VOLY - median**	**VSL - median**	**VOLY - mean**	**VSL - mean**
O_3 mortality	**VOLY - median**	**VOLY - median**	**VOLY - mean**	**VOLY - mean**
Health core?	**Yes**	**Yes**	**Yes**	**Yes**
Health sensitivity?	**No**	**No**	**Yes**	**Yes**
Crops	**Yes**	**Yes**	**Yes**	**Yes**
O_3/health metric	**SOMO 35**	**SOMO 35**	**SOMO 0**	**SOMO 0**
Austria	8300	13000	16000	24000
Belgium	11000	16000	21000	31000
Cyprus	-	-	-	-
Czech Republic	8000	12000	16000	23000
Denmark	5200	8100	10000	15000
Estonia	1800	2800	3600	5200
Finland	1800	2700	3500	5100
France	8000	12000	16000	23000
Germany	11000	17000	22000	32000
Greece	1400	2100	2700	4000
Hungary	4800	7300	9400	14000
Ireland	4800	7500	9500	14000
Italy	6100	9300	12000	18000
Latvia	2000	3100	3900	5700
Lithuania	2400	3600	4700	6800
Luxembourg	9800	15000	19000	28000
Malta	2200	3300	4300	6200
Netherlands	13000	21000	26000	39000
Poland	5600	8600	11000	16000
Portugal	3500	5400	6900	10000
Slovakia	4900	7500	9600	14000
Slovenia	6200	9500	12000	18000
Spain	4300	6600	8400	12000
Sweden	2800	4300	5500	8100
United Kingdom	6600	10000	13000	19000
Baltic Sea	3700	5800	7400	11000
Mediterranean Sea	2000	3200	4000	5900
North East Atlantic	2200	3400	4300	6300
North Sea	6900	11000	14000	20000

Annex 12, Table 4: Marginal SO_2 damage in EUR per tonne emission for 2010 with three sets of sensitivity analysis.

VOC – values in EUR/t

PM mortality **O_3 mortality** **Health core?** **Health sensitivity?** **Crops** **O_3/health metric**	**VOLY - median** **VOLY - median** **Yes** **No** **Yes** **SOMO 35**	**VSL - median** **VOLY - median** **Yes** **No** **Yes** **SOMO 35**	**VOLY - mean** **VOLY - mean** **Yes** **Yes** **Yes** **SOMO 0**	**VSL - mean** **VOLY - mean** **Yes** **Yes** **Yes** **SOMO 0**
Austria	1700	2600	3800	5200
Belgium	2500	3500	5300	7100
Cyprus	-	-	-	-
Czech Republic	1000	1400	2300	3000
Denmark	720	970	1600	2000
Estonia	140	190	340	420
Finland	160	220	390	490
France	1400	2000	3100	4200
Germany	1700	2500	3900	5100
Greece	280	400	670	880
Hungary	860	1300	2000	2700
Ireland	680	950	1600	2000
Italy	1100	1600	2600	3500
Latvia	220	300	520	650
Lithuania	230	330	550	710
Luxembourg	2700	4000	5900	8000
Malta	430	580	1000	1300
Netherlands	1900	2700	4100	5400
Poland	630	900	1400	1900
Portugal	500	700	1200	1600
Slovakia	660	960	1500	2000
Slovenia	1400	2000	3200	4400
Spain	380	510	920	1100
Sweden	330	440	780	980
United Kingdom	1100	1600	2500	3200
Baltic Sea	530	700	1200	1500
Mediterranean Sea	340	470	790	1000
North East Atlantic	390	540	900	1200
North Sea	1900	2600	4000	5400

Annex 12, Table 5: Marginal VOC damage in EUR per tonne emission for 2010, with three sets of sensitivity analysis.

Averages

PM mortality	**VOLY median**	**VSL median**	**VOLY mean**	**VSL mean**
O_3 mortality	**VOLY median**	**VOLY median**	**VOLY mean**	**VOLY mean**
Health core?	**Included**	**Included**	**Included**	**Included**
Health sensitivity?	**Not included**	**Not included**	**Included**	**Included**
Crops	**Included**	**Included**	**Included**	**Included**
O_3/health metric	**SOMO 35**	**SOMO 35**	**SOMO 0**	**SOMO 0**
EU25 (excluding Cyprus) averages – EUR/t				
NH_3	11000	16000	21000	31000
NO_X	4400	6600	8200	12000
$PM_{2.5}$	26000	40000	51000	75000
SO_2	5600	8700	11000	16000
VOCs	950	1400	2100	2800
Seas averages – EUR/t				
NH_3	n/a	n/a	n/a	n/a
NO_X	2500	3800	4700	6900
$PM_{2.5}$	13000	19000	25000	36000
SO_2	3700	5700	7300	11000
VOCs	780	1100	1730	2300

Annex 12, Table 6: Average damages in EUR per tonne of emission of NH_3, NO_X, $PM_{2.5}$, SO_2 and VOCs for the EU25 (excluding Cyprus) and surrounding sea areas under different sets of assumptions.

ANNEX 13 - METHODOLOGIES USED IN MEMBER STATES

United Kingdom

Methodologies that can be used to determine permit conditions at an installation in the UK are described in 'Environmental Assessment and Appraisal of BAT – IPPC H1 Horizontal Guidance Note' (draft) [18, UK Environment Agencies, 2002] (The Environment Agency for England and Wales, The Northern Ireland Environment and Heritage Service and the Scottish Environmental Protection Agency). The guidance is used as part of the permitting process and guides the user through the steps necessary to appraise the alternative options, to quantify their environmental impacts, to evaluate the costs and ultimately to determine which option should be implemented at a site.

The guidance is available on the worldwide web (link below) and has an accompanying software tool that performs the necessary calculations.

http://www.environment-agency.gov.uk/commondata/105385/h1extconsjuly.pdf

Belgium

The MIOW+ method is a computer program that is used to analyse the financial effects of investing in future environmental measures for individual companies. The results of MIOW+ analysis are used as a starting point for negotiations between the company and the authorities.

Estimated additional environmental costs are compared to the current and the expected financial situation that would exist if these measures were not implemented. It is a way of checking the resilience of a sector to the predicted environmental costs. The financial situation is characterised by means of a number of internal and external indicators. The weighted average of the internal indicators results in a score for 'resilience' ('Weerstandsvermogen') and the average of the external indicators results in a score for 'market situation'. The values derived for resilience and market situation determine the possibility of absorbing extra environmental costs internally, or the ability to transfer them to clients. Running the model and interpreting the results demands financial expertise. An expert opinion is necessary, particularly with regard to future developments and for the assessment of the competitive position.

Finland

The report 'Evaluation of environmental cross-media and economic aspects in industry – Finnish BAT expert case study' [17, Vasara, et al., 2002] provides background information for integrated environmental permitting in Finland. Different methods and approaches for economic and cross-media evaluation were identified, discussed and demonstrated with practical examples from pulp and paper production as well as energy production. A particular emphasis was placed on practical application in permitting context.
The document is available from the website http://www.environment.fi and
http://www.environment.fi/default.asp?contentid=58397&lan=EN

Several cross-media conflicts, proceeding from simpler to more complicated ones, were highlighted with possible methods to deal with the problems. The applicability of the methodologies was assessed and discussed. The dimensions of trade-offs and possible conflicts cover air, water, soil, energy, time, product quality and costs. The methods are targeted for the local level, whereas their use on EU level is not endorsed due to the significant variations in natural, anthropogenic and technological environment between facilities in different localities across Europe. Methodologies on investment appraisal (e.g. net present value) and cost allocation, (e.g. activity based costing) are described.

Germany

Some of the early work that was undertaking during the development of the cross-media assessment is described in the document ‘Cross-media assessment of environmental impacts caused by specific industrial activities’. (Goetz, Rippen et al. 2001) The document describes the steps involved in carrying out a cross-media assessment and follows the structure:

Step 1: ‘Preparatory work’
First, the technologies that are available must be selected and examined as to whether they are mutually exchangeable, i.e. if they are true alternatives for operators. Exclusion criteria can be used for specific technologies: Techniques that have, for example, not been tested on a large commercial scale or which do not meet internationally accepted environmental standards will not be classified as BAT and therefore are not considered any further.

Step 2: ‘Identification of the media conflict’
The environmental pollution that can be expected from the techniques is qualitatively assessed and compared. The differences in the individual environmental performance of the compared techniques are focused, so that data quantities, which have to be considered, can be substantially reduced.

Step 3: ‘Data gathering’
Data is gathered on emissions of contaminants (in the air and water), the consumption of energy and auxiliary materials and waste disposal for the limited area for which the balance sheet is to be prepared. The expenses for the three data areas are calculated as primary energy consumption (or cumulated energy demand CED).

Step 4: ‘Standardisation and comparison’
4.1 Industry-related standardisation
The results of the balance sheet for emission loads and CED are placed in relation to the respective total burden or, alternatively, the total energy consumption in Germany or the EU (e.g. on the basis of population equivalents). When the differences between the alternative technologies are extrapolated to the total capacity of the respective industry, this shows the quantitative significance of emissions or energy consumption and only one or the other technology would then be deployed.
4.2 Environment-related standardisation
A standard propagation scenario in the surrounding air or in a receiving body of water is drawn up for the direct emissions of a typical plant using the technologies that are to be assessed. The estimated immission values are compared to media-related quality targets (reference immission values) (location-independent immission consideration).

Step 5: ‘Final assessment’
In order to identify relevant environmental aspects, relevance thresholds are suggested for the differences between the alternative technologies that were determined in the industry and environment-related standardisation procedures. These can only have an orientation character. For the industry-related assessment a relevance threshold of 10000 population equivalents is recommended as a significant difference between the standardisation results. For the environment-related standardisation, a 1 % excess of the respective immission guide value is recommended. The different substances that are emitted are not weighted as regards their ecological effects. Like the allocation BAT/non BAT, this assessment is to be made on an expert level, which can also take account of current environmental-political points of view.

ANNEX 14 - PRINTING PRESS EXAMPLE

Introduction

This example helps to illustrate the application of the various guidelines presented in this document. Two alternative options for flexo graphic printing are compared by using the cross-media methodology. Alternative techniques for printing 2400 tonnes of paper per year are considered. These alternative techniques are: (1) printing with solvent-based ink, or (2) printing with water based ink.

Emission figures indicated in this example are solely for the purpose of illustrating the method. The actual emissions can vary significantly according to, e.g. the type of solvent used, the printing technique and the quality of the printing equipment.

Although ‘cumulated energy demand’ and ‘abiotic depletion’ are excluded from the methodologies presented elsewhere in the document, they were part of this example and are, therefore, retained. The use of CED extends the evaluation of the environmental effects of the process beyond the IPPC process boundary and there is some concern that it could lead to double counting some of the environmental effects. There is also concern about the validity of the numbers used in the assessment for abiotic depletion and concerns that this again went beyond the boundaries of the IPPC process.

Concerns over the use of abiotic depletion include the following:

- the assessment is dominated by the energy consumed by the process. There are no abiotic depletion potential factors available for the solvents used, so the calculation has only been carried out for the fuels used in generating the energy used in the process
- a number of arbitrary choices have been made in establishing the figures (particularly for calculation of the resource availability). It is very difficult to verify or validate the figures that have been derived
- the final calculated values depend on the quantity of prospecting that has been carried out for that particular resource and on the extrapolation work carried out by the researcher to establish the total reserves available
- the depletion of one resource does not necessarily have the same impact as the depletion of another
- the scientific validity of assessing abiotic depletion is very weak and several alternative lists are available, but all differ depending on the assumptions that have been used to calculate the abiotic depletion potentials
- abiotic depletion as a criterion for assessment does not attract the same magnitude of importance from the decision-maker as, for example, toxicity potentials, global warming potentials or acidification.

For completeness, lists of CEDs for various activities, and abiotic depletion potentials for some chemicals are retained towards the back of this annex.

The following example is structured according to the sequence of guidelines.

GUIDELINE 1 - Scope and identify the alternative options

Two alternative options for flexo graphic printing for a process that would print 2400 tonnes of paper per year are considered. The base data for the two options are given below:

		Quantity used or emitted	
Emissions or consumptions	**Units**	**Option 1: Solvent-based**	**Option 2: Water-based**
Ethyl acetate (air)	kg	7368	1650
Ethanol (air)	kg	7342	3977
Isopropanol (air)	kg	4904	3501
Ethoxypropanol (air)	kg	2669	
Butanone (air)	kg	1219	
Methylisobutylketone (air)	kg	1219	
Toluene (air)	kg	269	
Xylene (air)	kg	269	
Gasoline (air)	kg		4880
Ammonia (air)	kg		1400
AOX (water)	kg		0.028
COD (water)	kg		69
Chromium (water)	kg		0.001
Copper (water)	kg		0.015
Nickel (water)	kg		0.0054
Ammonium (water)	kg		0.87
Nitrate (water)	kg		9.7
Waste	kg	15700	5000
Energy, electricity (materials)	TJ	12.2	6.8
Energy, electricity (primary consumption)	TJ	4.4	2.3
Energy, heat (primary Consumption)	TJ	1.6	2.4
Total energy	**TJ**	**18.2**	**11.5**

The following processes are included in the system boundaries:

- for solvent-based printing: the manufacturing of solvents, binders, auxiliary agents and printer's ink, the printing process and the thermal afterburning of solvent vapours, energy and waste
- for water-based printing: the manufacturing of solvents, binders, auxiliary agents and printer's ink the printing process and the internal and municipal sewage plant, energy and waste.

In both cases, the 'energy, electricity (materials)' is calculated from the 'cumulated energy demand'.

Annex 14, Table 1: Comparison of two options – solvent-based and water-based process for flexo graphic printing
(based on 2400 tonnes paper per year) Data from Oekopol 2000.

Simplification techniques applied:

- the quantity of pigments is the same for both processes. It is, therefore, omitted from the analysis as it is a common factor to both
- disposal processes are left out of the analysis. The waste from the process is considered to be the final waste with no analysis of its composition
- the manufacturing processes for solvents, binders, auxiliary agents and printer's ink are included in the analysis, but only in terms of energy consumption (cumulated energy demand since most of the associated environmental aspects are related to energy use).

Cross-media conflict

From an examination of the base data, there is a cross-media conflict between the higher air emissions (VOCs – ethyl acetate, ethanol, etc) of the solvent-based process versus the waste water discharges of the water-based process. The influence of energy consumption and waste production of both processes is still unclear.

Conclusion after following Guideline 1

At this point, no conclusion can be drawn regarding the environmental performance of these processes, because the option that provides the higher level of protection to the environment is not obvious. The analysis, therefore, is continued using Guideline 2.

GUIDELINE 2 - Inventory of emissions

Energy related upstream emissions or consumptions for the solvent-based printing process

The multiplication factors in column 3 below are taken from the European energy mix data in Annex 8. The data in columns 4, 5 and 6 were calculated by multiplying the information on the energy used (in GJ) from the inventory by the multiplication factors in column 3.

1	2	3	4	5	6
		Multiplication factors from Annex 8	Energy electricity (materials)	Energy electricity (primary consumption)	Energy heat (primary consumption)
Energy used in the solvent-based process	TJ		12.2	4.4	1.6
	GJ		$12.2*10^3$	$4.4*10^3$	$1.6*10^3$
Electricity	GJ	1	12200	4400	
Primary energy	GJ	2.57	31354	11308	
Oil	kg	9.01	109922	39644	
Gas	m^3	6.92	84424	30448	
Coal	kg	0.13	1586	572	
Brown coal	kg	34.64	422608	152416	
SO_2	kg	0.1	1220	440	
CO_2	kg	116.71	1423862	513524	
NO_2	kg	0.16	1952	704	
Steam	GJ	1			1600
Primary energy	GJ	1.32			2112
Oil	kg	12.96			20736
Gas	m^3	10.46			16736
Coal	kg	14.22			22752
SO_2	kg	0.54			864
CO_2	kg	97.2			155520
NO_2	kg	0.18			

Annex 14, Table 2: Energy related upstream emissions or consumptions in the solvent-based process

The totals in the table below are the sum of the total fuels used and pollutants emitted by the energy used in the electricity used to produce the materials (CED), the electricity used directly in the process and the steam used directly in the process. They were calculated by summing the data that was calculated in columns 4, 5 and 6 of the table above.

Solvent process		
Oil (utilisation)	kg	170302
Gas (utilisation)	m^3	131608
Coal (utilisation)	kg	23482
SO_2 (emission)	kg	2524
CO_2 (emission)	kg	1630706
NO_2 (emission)	kg	2944

Annex 14, Table 3: Summary of the energy related emissions or consumptions in the solvent-based process

Energy related upstream emissions or consumptions for water-based process

The multiplication factors in column 3 below are taken from the European energy mix data in Annex 8. The data in columns 4, 5 and 6 were calculated by multiplying the information on the energy used (in GJ) from the inventory by the multiplication factors in column 3.

1	2	3	4	5	6
		Multiplication factors from Annex 8	**Energy electricity (materials)**	**Energy electricity (primary consumption)**	**Energy heat (primary consumption)**
Energy used in the water-based process	TJ		6.8	2.3	2.4
	GJ		$6.8*10^3$	$2.3*10^3$	$2.4*10^3$
Electricity	GJ	1	6800	2300	
Primary energy	GJ	2.57	17476	5911	
Oil	kg	9.01	61268	20723	
Gas	m^3	6.92	47056	15916	
Coal	kg	0.13	884	299	
Brown Coal	kg	34.64	249152	79672	
SO_2	kg	0.1	680	230	
CO_2	kg	116.71	793628	268433	
NO_2	kg	0.16	1088	368	
Steam	GJ	1			2400
Primary energy	GJ	1.32			3168
Oil	kg	12.96			31104
Gas	m^3	10.46			25104
Coal	kg	14.22			34128
SO_2	kg	0.54			1296
CO_2	kg	97.2			233280
NO_2	kg	0.18			432

Annex 14, Table 4: Energy related upstream emissions or consumptions in the water-based process

The totals in the table below are the sum of the total fuels used and pollutants emitted by the energy used in the electricity used to produce the materials (CED), the electricity used directly in the process and the steam used directly in the process. These totals are calculated by summing the data that were calculated in column 4, 5 and 6 of the table above.

Water process		
Oil (utilisation)	kg	113095
Gas (utilisation)	m^3	88076
Coal (utilisation)	kg	35311
SO_2 (emission)	kg	2206
CO_2 (emission)	kg	1295341
NO_2 (emission)	kg	1888

Annex 14, Table 5: Summary of the energy related emissions or consumptions in the water-based process

Summary of the emissions or consumptions from both printing processes

After calculating the energy related upstream emissions or consumptions, the inventory of emissions and consumptions for the two options can be compared as below.

Environmental emissions or consumptions		OPTION 1 Solvent-based printing	OPTION 2 Water-based printing
Ethyl acetate (air)	kg	7368	1650
Ethanol (air)	kg	7342	3977
Isopropanol (air)	kg	4904	3501
Ethoxypropanol (air)	kg	2669	-
Butanone (air)	kg	1219	-
Methylisobutylketone (air)	kg	1219	-
Toluene (air)	kg	269	-
Xylene (air)	kg	269	-
Gasoline (air)	kg	-	4880
Ammonia (air)	kg	-	1400
AOX (water)	kg	-	0.028
COD (water)	kg	-	69
Chromium (water)	kg	-	0.001
Copper (water)	kg	-	0.015
Nickel (water)	kg	-	0.0054
Ammonium (water)	kg	-	0.87
Nitrate (water)	kg	-	9.7
Energy	TJ	18.2	11.5
Waste	kg	15700	5000
Oil (utilisation)	kg	170302	113095
Gas (utilisation)	m^3	131608	88076
Coal (utilisation)	kg	23482	35311
SO_2 (emission)	kg	2524	2206
CO_2 (emission)	kg	1630706	1295341
NO_2 (emission)	kg	2944	1888

Annex 14, Table 6: Summary of the emissions or consumptions from the alternative printing processes

It is obvious from this inventory and the calculations, that the solvent-based process releases more solvents and uses more oil and gas. The water-based process uses more coal and has releases to water. The solvent-based process therefore releases greater quantities of SO_2, CO_2 and NO_2 from the energy used, than the water-based process. The differences in coal, oil and gas usage are because of the higher energy demand for the solvent-based process and the different energy mix.

Data quality

For each process, the extractions and emissions were collected, based on the printing of 2400 tonnes of paper per year. The data was collected for the printing processes, the afterburning of solvent vapours and for the water treatment plant, based on the average data from several operating plants in Germany.

Using the data quality rating system, the data for this example can be rated ‘C’: i.e. data are an estimate based on a limited amount of information representative of some situations and for which background assumptions are limited. However, it has not been possible to trace and validate the original data.

Conclusion after following Guideline 2

There still remains a cross-media conflict. The user and the decision-maker will have to weigh up the relative merits of the higher air emissions from the VOCs used and the energy used in solvent-based process against the higher water releases in the water-based process.

GUIDELINE 3 - Calculate the cross-media effects

Human toxicity

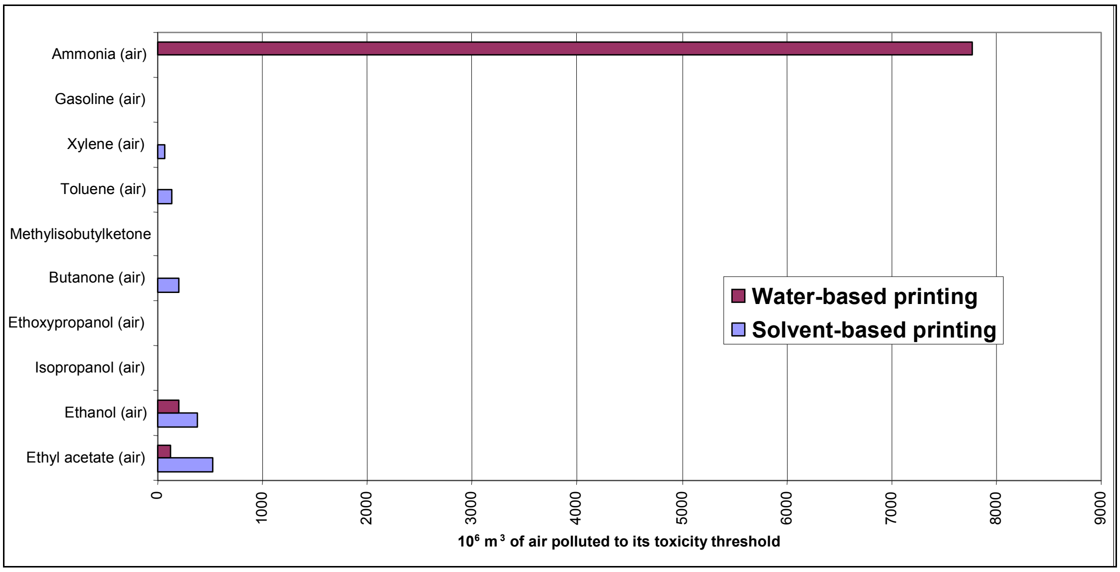
The human toxicity potentials for the two alternative options are presented in the table below.

Human toxicity potentials							
Example: solvent-based printing versus water-based printing							
Environmental emissions or consumption		OPTION 1			OPTION 2		
		Solvent-based printing			Water-based printing		
		Mass release	Human toxicity threshold µg/m^3	Volume of air polluted to its toxicity threshold in m^3	Mass release	Human toxicity threshold µg/m^3	Volume of air polluted to its toxicity threshold in m^3
Ethyl acetate (air)	kg	7368	14600	504657534	1650	14600	113013698
Ethanol (air)	kg	7342	19200	382395833	3977	19200	207135417
Isopropanol (air)	kg	4904			3501		
Ethoxypropanol (air)	kg	2669			-		
Butanone (air)	kg	1219	6000	203166667	-	6000	
Methylisobutylketone (air)	kg	1219			-		
Toluene (air)	kg	269	1910	140837696	-	1910	
Xylene (air)	kg	269	4410	60997732	-	4410	
Gasoline (air)	kg	-			4880		
Ammonia (air)	kg	-			1400	180	7777777778
AOX (water)	kg	-			0		
COD (water)	kg	-			69		
Chromium (water)	kg	-			0		
Copper (water)	kg	-			0		
Nickel (water)	kg	-			0		
Ammonium (water)	kg	-			1		
Nitrate (water)	kg	-			10		
Waste	kg	15700			5000		
Energy, electricity (materials)	TJ	12			7		
Energy, electricity (primary consumption)	TJ	4			2		
Energy, heat (primary consumption)	TJ	2			2		
Inventory table of energy related emissions and consumption rates from upstream processes.							
CO$_2$ (air emission)	kg	1630706			1295341		
SO$_2$ (air emission)	kg	2524	50	50480000000	2206	50	44120000000
NO$_2$ (air emission)	kg	2944	40	73600000000	1888	40	47200000000
Coal (extraction)	kg	23482			35311		
Oil (extraction)	kg	170302			113095		
Gas (extraction)	m^3	**131608**			**88076**		
Total volume of air polluted to its toxicity threshold in m^3				**125 x 10^9**			**99 x 10^9**

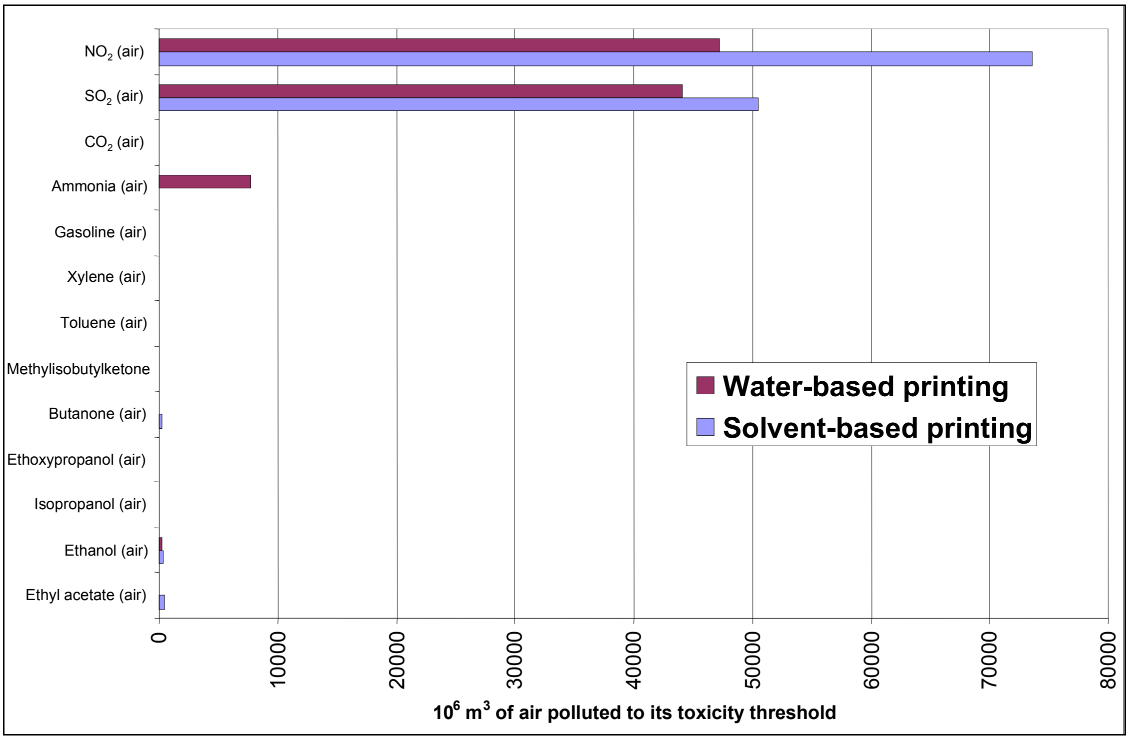
Annex 14, Table 7: Human Toxicity potentials of the two printing process options

From these results it is obvious that the solvent-based printing methodology has the larger human toxicity effects of the two options (125 x 10^9 m^3 of air polluted to its toxicity threshold compared to 99 x 10^9 m^3 for the water-based process). Therefore, with respect to human toxicity potential, the water-based printing methodology is preferable. However, the user needs to be careful when interpreting the results, as the dominant source of the human toxicity effect is, in fact, the pollutants released from the energy used. An alternative power source could well change the balance of the decision.

From the graphical representations of the results below, it is obvious that the human toxicity effects of the direct releases are dominated by the ammonia release from the water-based printing process. When the releases from the energy used are also considered (presented in the second graph), the dominant effect becomes the nitrogen dioxide and sulphur dioxide releases from the power consumed by the solvent-based process.



Annex 14, Figure 1: Human toxicity potential of direct releases (excluding power consumption)



Annex 14, Figure 2: Human toxicity potential (including the releases from power consumption)

Notes

The following paragraphs expose and discuss some weaknesses with this methodology.

1) In this example, the nitrogen dioxide and sulphur dioxide released from the power station dominates the human toxicity potential. If the power was derived from an alternative source (e.g. gas fired power station, or nuclear), then this would change the balance completely. This becomes obvious if the results from the direct emissions and energy related emissions are presented separately (see the Figures above). In this instance the first reaction would be to carry out sensitivity analyses of the power consumption and of the multiplication factors used in determining the emissions from the power consumed. This has a critical influence in the decision making and may well be skewed depending on whether the 'European energy mix' data or more local information is used.

2) In this case, a human toxicity potential of 50 $\mu g/m^3$ was used for SO_2 (long-term UK benchmark from occupational exposure limit). If the short-term exposure limits had been used, then the ratios between SO_2 and NO_2 would change, as the ratio between long-term and short-term exposure limits are not fixed. Different pollutants have different long-term and short-term effects, which makes it difficult to make direct comparisons between pollutants. When carrying out the assessment, the long-term and short-term figures should not be mixed but it is unclear whether it is preferable to use the long-term or the short-term figures or whether both figures should be assessed.

3) Isopropanol and ethoxypropanol and methylisobutylketone do not have human toxicity thresholds either. Alternative names have been checked but no factors were found:
   a) for isopropanol – the alternative names are isopropyl alcohol, 2-propanol, dimethyl carbinol, sec-propyl alcohol
   b) for ethoxypropanol – the alternative names are propylene glycol and monoethyl ether.
   c) for methylisobutylketone – the alternative names are isobutyl methyl ketone, methyl isobutyl ketone, 4-methyl 2-pentanone, MIBK.

4) What guidance can we give to the user in these circumstances? Can they be derived using the UK derivation methodology presented in Annex 1 (1/100th of an occupational exposure limit, 1/500th of a maximum exposure limit) using NIOSH recommended exposure limits (RELs) from the NIOSH database. This database has a more comprehensive coverage and is also accessible from the internet.

   http://www.cdc.gov/niosh/npg/npgd0000.html.

Global Warming Potential

The global warming potentials for the two options are presented in the table below.

Global warming potentials							
Example: solvent-based printing versus water-based printing							
Environmental emissions or consumptions		OPTION 1			OPTION 2		
		Solvent-based printing			Water-based printing		
		Mass released	Global warming potential	CO_2 equivalent	Mass released	Global warming potential	CO_2 equivalent
Ethyl acetate (air)	kg	7368			1650		
Ethanol (air)	kg	7342			3977		
Isopropanol (air)	kg	4904			3501		
Ethoxypropanol (air)	kg	2669			-		
Butanone (air)	kg	1219			-		
Methylisobutylketone (air)	kg	1219			-		
Toluene (air)	kg	269			-		
Xylene (air)	kg	269			-		
Gasoline (air)	kg	-			4880		
Ammonia (air)	kg	-			1400		
AOX (water)	kg	-			0.028		
COD (water)	kg	-			69		
Chromium (water)	kg	-			0.001		
Copper (water)	kg	-			0.015		
Nickel (water)	kg	-			0.0054		
Ammonium (water)	kg	-			0.87		
Nitrate (water)	kg	-			9.7		
Waste	kg	15700			5000		
Energy, electricity (materials)	TJ	12.2			6.8		
Energy, electricity (primary consumption)	TJ	4.4			2.3		
Energy, heat (primary consumption)	TJ	1.6			2.4		
Inventory table of energy related emissions and consumption rates from upstream processes.							
CO_2 (air emission)	kg	1630706	1	1630706	1295341	1	1295341
SO_2 (air emission)	kg	2524			2206		
NO_2 (air emission)	kg	2944			1888		
Coal (extraction)	kg	23482			35311		
Oil (extraction)	kg	170302			113095		
Gas (extraction)	m^3	131608			88076		
Total kg CO_2 equivalent				**1630706**			**1295341**

Annex 14, Table 8: Global warming potentials of the two printing process options

From this assessment, the water-based printing technique is again preferred to the solvent-based technique as it has a lower global warming potential (i.e. 1295341 compared to 1630706 kg CO_2 equivalent). Users should again note that the greenhouse gases released in this example result from the energy used in the process, and that the concerns about the information used to derive these emissions also apply here.

Aquatic Toxicity

The aquatic toxicity potentials for the two options are presented in the table below.

Aquatic toxicity potential							
Example: solvent-based printing versus water-based printing							
Environmental emissions or consumptions		OPTION 1			OPTION 2		
		Solvent-based printing			Water-based printing		
		Mass released	Aquatic Toxicity threshold µg/m^3	Volume of water polluted m^3	Mass released	Aquatic Toxicity threshold µg/m^3	Volume of water polluted m^3
Ethyl acetate (air)	kg	7368			1650		
Ethanol (air)	kg	7342			3977		
Isopropanol (air)	kg	4904			3501		
Ethoxypropanol (air)	kg	2669			-		
Butanone (air)	kg	1219			-		
Methylisobutylketone (air)	kg	1219			-		
Toluene (air)	kg	269			-		
Xylene (air)	kg	269			-		
Gasoline (air)	kg	-			4880		
Ammonia (air)	kg	-			1400		
AOX (water)	kg	-			0.028		
COD (water)	kg	-			69		
Chromium (water)	kg	-			0.001	0.0085	117.65
Copper (water)	kg	-			0.015	0.0011	13636.36
Nickel (water)	kg	-			0.0054	0.0018	3000.00
Ammonium (water)	kg	-			0.87		
Nitrate (water)	kg	-			9.7		
Waste	kg	15700			5000		
Energy, electricity (materials)	TJ	12.2			6.8		
Energy, electricity (primary consumption)	TJ	4.4			2.3		
Energy, heat (primary consumption)	TJ	1.6			2.4		
Inventory table of energy related emissions and consumption rates from upstream processes.							
CO_2 (air emission)	kg	1630706			1295341		
SO_2 (air emission)	kg	2524			2206		
NO_2 (air emission)	kg	2944			1888		
Coal (extraction)	kg	23482			35311		
Oil (extraction)	kg	170302			113095		
Gas (extraction)	m^3	131608			88076		
Total volume of water polluted to its toxicity threshold m^3				**0**			**16754**

Annex 14, Table 9: Aquatic toxicity potentials of the two printing process options

From this calculation, the solvent-based process is the preferred option, as it has no impact on the aquatic environment, whereas the water-based process has a small impact.

Acidification potential

The acidification potentials for the two options are presented in the table below.

Acidification potentials							
Example: solvent-based printing versus water-based printing							
Environmental emissions or consumptions		OPTION 1			OPTION 2		
		Solvent-based printing			Water-based printing		
		Mass emission	Acidification potential	SO_2 equivalent	Mass emission	Acidification potential	SO_2 equivalent
Ethyl acetate (air)	kg	7368			1650		
Ethanol (air)	kg	7342			3977		
Isopropanol (air)	kg	4904			3501		
Ethoxypropanol (air)	kg	2669			-		
Butanone (air)	kg	1219			-		
Methylisobutylketone (air)	kg	1219			-		
Toluene (air)	kg	269			-		
Xylene (air)	kg	269			-		
Gasoline (air)	kg	-			4880		
Ammonia (air)	kg	-			1400	1.6	2884
AOX (water)	kg	-			0.028		
COD (water)	kg	-			69		
Chromium (water)	kg	-			0.001		
Copper (water)	kg	-			0.015		
Nickel (water)	kg	-			0.0054		
Ammonium (water)	kg	-			0.87		
Nitrate (water)	kg	-			9.7		
Waste	kg	15700			5000		
Energy, electricity (materials)	TJ	12.2			6.8		
Energy, electricity (primary consumption)	TJ	4.4			2.3		
Energy, heat (primary consumption)	TJ	1.6			2.4		
Inventory table of energy related emissions and consumption rates from upstream processes.							
CO_2 (air emission)	kg	1630706			1295341		
SO_2 (air emission)	kg	2524	1.2	3028	2206	1.2	2647
NO_2 (air emission)	kg	2944	0.5	1472	1888	0.5	944
Coal (extraction)	kg	23482			35311		
Oil (extraction)	kg	170302			113095		
Gas (extraction)	m^3	131608			88076		
Total acidification potential in kg SO_2 equivalents				**4500**			**6475**

Annex 14, Table 10: Acidification potentials of the two printing process options

In this example, the solvent-based printing process is preferred, as it has less of an acidification effect than the water-based process (4500 kg SO_2 equivalents as opposed to 6475 kg SO_2 equivalents).

Eutrophication potential

The eutrophication potentials for the two options in the printing process example are presented in the table below.

Eutrophication potentials							
Example: solvent-based printing versus water-based printing							
Environmental emissions or consumptions		OPTION 1			OPTION 2		
		Solvent-based printing			Water-based printing		
		Mass emission	Eutrophication potential	PO_4^{3-} equivalents	Mass emission	Eutrophication potential	PO_4^{3-} equivalents
Ethyl acetate (air)	kg	7368			1650		
Ethanol (air)	kg	7342			3977		
Isopropanol (air)	kg	4904			3501		
Ethoxypropanol (air)	kg	2669			-		
Butanone (air)	kg	1219			-		
Methylisobutylketone (air)	kg	1219			-		
Toluene (air)	kg	269			-		
Xylene (air)	kg	269			-		
Gasoline (air)	kg	-			4880		
Ammonia (air)	kg	-			1400	0.35	490
AOX (water)	kg	-			0.028		
COD (water)	kg	-			69	0.022	1.518
Chromium (water)	kg	-			0.001	0	
Copper (water)	kg	-			0.015		
Nickel (water)	kg	-			0.0054		
Ammonium (water)	kg	-			0.87	0.33	0.287
Nitrate (water)	kg	-			9.7	0.1	0.97
Waste	kg	15700			5000		
Energy, electricity (materials)	TJ	12.2			6.8		
Energy, electricity (primary consumption)	TJ	4.4			2.3		
Energy, heat (primary consumption)	TJ	1.6			2.4		
Inventory table of energy related emissions and consumption rates from upstream processes							
CO_2 (air emission)	kg	1630706			1295341		
SO_2 (air emission)	kg	2524			2206		
NO_2 (air emission)	kg	2944	0.13	383	1888	0.13	245
Coal (extraction)	kg	23482			35311		
Oil (extraction)	kg	170302			113095		
Gas (extraction)	m^3	131608			88076		
Total kg PO_4^{3-} equivalent				**383**			**738**

Annex 14, Table 11: Eutrophication potentials of the two printing process options

In this case, the solvent-based printing option is preferable to the water-based process.

Ozone depletion potential

No ozone depleting chemicals were released in the printing process example from either of the two options.

Photochemical ozone creation potential

The photochemical ozone creation potentials for the two options are presented below.

Photochemical ozone creation potentials							
Example: solvent-based printing versus water-based printing							
Environmental emissions or consumptions		OPTION 1			OPTION 2		
		Solvent-based printing			Water-based printing		
		Mass emission	POCP	POCP in kg ethylene equivalents	Mass emission	POCP	POCP in kg ethylene equivalents
Ethyl acetate (air)	kg	7368	0.209	1540	1650	0.209	344
Ethanol (air)	kg	7342	0.399	2929	3977	0.399	1587
Isopropanol (air)	kg	4904			3501		
Ethoxypropanol (air)	kg	2669			-		
Butanone (air)	kg	1219			-		
Methylisobutylketone (air)	kg	1219	0.49	597	-	0.49	
Toluene (air)	kg	269	0.637	171	-	0.637	
Xylene (air)	kg	269	1.108	298	-	1.108	
Gasoline (air)	kg	-			4880		
Ammonia (air)	kg	-			1400		
AOX (water)	kg	-			0.028		
COD (water)	kg	-			69		
Chromium (water)	kg	-			0.001		
Copper (water)	kg	-			0.015		
Nickel (water)	kg	-			0.0054		
Ammonium (water)	kg	-			0.87		
Nitrate (water)	kg	-			9.7		
Waste	kg	15700			5000		
Energy, electricity (materials)	TJ	12.2			6.8		
Energy, electricity (primary consumption)	TJ	4.4			2.3		
Energy, heat (primary consumption)	TJ	1.6			2.4		
Inventory table of energy related emissions and consumption rates from upstream processes							
CO_2 (air emission)	kg	1630706			1295341		
SO_2 (air emission)	kg	2524	0.048	121	2206	0.048	106
NO_2 (air emission)	kg	2944	0.028	82	1888	0.028	53
Coal (extraction)	kg	23482			35311		
Oil (extraction)	kg	170302			113095		
Gas (extraction)	m^3	131608			88076		
Total kg ethylene equivalent				**5738**			**2088**

Annex 14, Table 12: Photochemical ozone creation potentials of the two printing process options

In this example, the water-based printing process is preferable to the solvent-based process because it has a lower POCP.

Abiotic depletion

The abiotic depletion potentials of the resources used in the two options are presented below.

Abiotic depletion							
Example: solvent-based printing versus water-based printing							
Environmental emissions or consumptions		OPTION 1			OPTION 2		
		Solvent-based printing			Water-based printing		
		Mass	Abiotic Depletion Potential	ADP in kg antimony	Mass	Abiotic Depletion Potential	ADP in kg antimony
Ethyl acetate (air)	kg	7368			1650		
Ethanol (air)	kg	7342			3977		
Isopropanol (air)	kg	4904			3501		
Ethoxypropanol (air)	kg	2669			-		
Butanone (air)	kg	1219			-		
Methylisobutylketone (air)	kg	1219			-		
Toluene (air)	kg	269			-		
Xylene (air)	kg	269			-		
Gasoline (air)	kg	-			4880		
Ammonia (air)	kg	-			1400		
AOX (water)	kg	-			0.028		
COD (water)	kg	-			69		
Chromium (water)	kg	-			0.001		
Copper (water)	kg	-			0.015		
Nickel (water)	kg	-			0.0054		
Ammonium (water)	kg	-			0.87		
Nitrate (water)	kg	-			9.7		
Waste	kg	15700			5000		
Energy, electricity (materials)	TJ	12.2			6.8		
Energy, electricity (primary consumption)	TJ	4.4			2.3		
Energy, heat (primary consumption)	TJ	1.6			2.4		
Inventory table of energy related emissions and consumption rates from upstream processes							
CO_2 (air emission)	kg	1630706			1295341		
SO_2 (air emission)	kg	2524			2206		
NO_2 (air emission)	kg	2944			1888		
Coal (extraction)	kg	23482	0.0134	315	35311	0.0134	473
Oil (extraction)	kg	170302	0.0201	3423	113095	0.0201	2273
Gas (extraction)	m^3	131608	0.0187	2461	88076	0.0187	1647
Total kg Antimony equivalent				**6199**			**4393**

Annex 14, Table 13: Abiotic depletion of the two printing process options

In this example, the solvent-based process uses up more abiotic resources than the water-based process, therefore the water-based process is the preferred option.

GUIDELINE 4 - Interpret the cross-media conflicts

Simple comparison of each of the environmental effects

For this example, the results of the assessment of each of the environmental themes is shown in the following table:

	Solvent-based process	Water-based process
Human toxicity potential		✓
Global warming potential		✓
Aquatic toxicity potential	✓	
Acidification potential	✓	
Eutrophication potential	✓	
Ozone depletion potential	-	-
Photochemical ozone creation potential		✓
Abiotic depletion		✓
Energy		✓
Waste		✓
Note: the preferred choice has the lowest environmental impact in each of the categories		

Annex 14, Table 14: Simple comparison of each of the environmental effects

At this stage the user should also highlight any environmental effects or pollutants that were not considered in the evaluation. For the printing process example, emissions of isopropanol, ethoxypropanol and methylisobutylketone were not considered as no multiplication factors have been derived for them, even though they are likely to have a photochemical ozone creation potential and possibly a human toxicity effect. The gasoline to air emission from the water-based printing process was not assessed as there are no effect factors derived for gasoline in any of the environmental themes considered, even though it is likely to have a photochemical ozone creation potential and possibly a human toxicity effect. No effect was calculated for the ammonium release to water either, again because of the absence of a multiplication factor even though the ammonium release is likely to have an eutrophication effect. Fortunately, in this case, ammonium was only a very small release.

When comparing the two printing process examples, the dominant effect was found to be the power consumed in the processes and the environmental effects that the production of that power had. Note the comments in Section 2.4.2 on the energy used in the process.

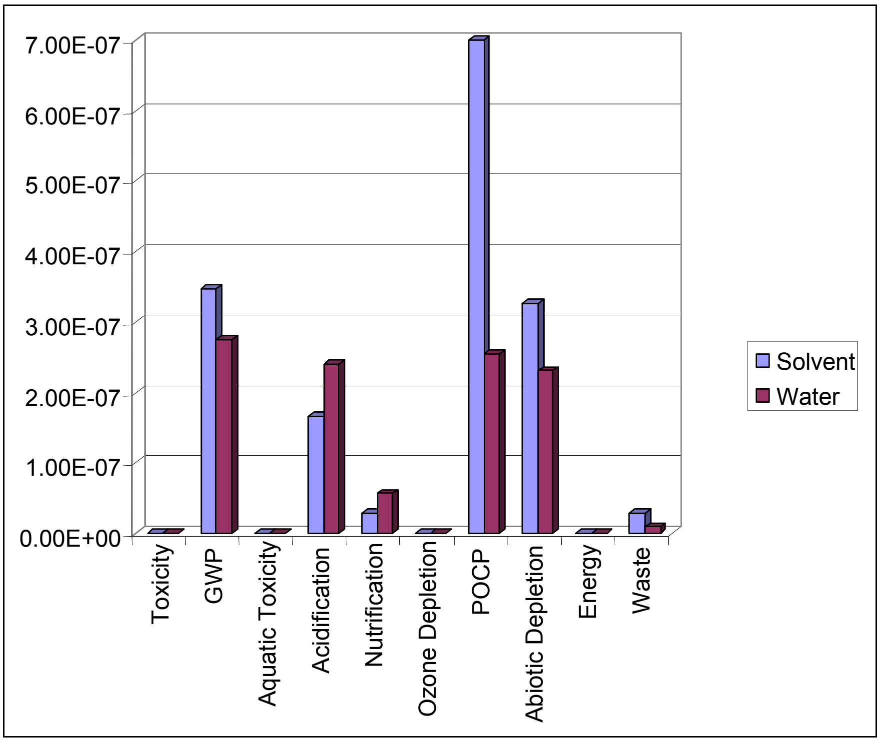
From the results presented here, the preferred option would be the water-based printing process. It has the lesser environmental impact for 4 of the 8 categories, and also consumes less energy and produces less waste.

This decision is based on simple, transparent comparisons between the options. As well as helping to identify the alternative with the lowest environmental impact, the transparency in the methodology allows the user to identify those issues that cause the greatest concern. The drawback of using this approach is that there is no consideration of the magnitude of the environmental effect. For example, the eutrophication effect from both of the alternatives was fairly small, but eutrophication has the same weighting as other bigger effects such as toxicity.

As a further step, a comparison with the European totals is presented in the table and figure below.

Effect	Units	Total European load	Solvent		Water	
			Total	Fraction of European total	Total	Fraction of European total
Human toxicity potential	m^3 of air	?	125 x 10^9	?	99 x 10^9	?
Global warming potential	kg CO^2 equivalents	4.7 x 10^{12}	1630706	3.47 x 10^{-7}	1295341	2.76 x 10^{-7}
Aquatic toxicity potential	m^3 of water	?	0	?	16754	?
Acidification potential	kg SO^2 equivalents	2.7 x 10^{10}	4500	1.67 x 10^{-7}	6475	2.4 x 10^{-7}
Eutrophication potential	kg PO_4^{3-} equivalent	1.3 x 10^{10}	383	2.95 x 10^{-8}	738	5.68 x 10^{-8}
Ozone depletion potential	kg CFC-11 equivalent	8.3 x 10^7		0		0
Photochemical ozone creation potential	kg ethylene equivalent	8.2 x 10^9	5738	6.99 x 10^{-7}	2088	2.55 x 10^{-7}
Abiotic depletion	kg Sb equivalent	1.9 x 10^{10}	6199	3.26 x 10^{-7}	4393	2.31 x 10^{-7}
Energy	TJ	6.1 x 10^{13}	18.2	2.98 x 10^{-13}	11.5	1.89 x 10^{-13}
Waste	kg	5.4 x 10^{11}	15700	2.91 x 10^{-8}	5000	9.26 x 10^{-9}

Annex 14, Table 15: Printing process options compared to European totals



Annex 14, Figure 3: Comparison of the two options with the European totals for the environmental themes

It can be seen from Annex 14, Figure 3 that photochemical ozone creation potential (POCP) is the theme where the alternatives have the greatest impact on the European total.

Users and decision-makers need to understand that confidence in these European totals is the weakest part of this methodology and this stage of the assessment should be used with great care.

Notes

1) European totals for human toxicity and aquatic toxicity have yet to be worked out.

2) The uncertainties surrounding these European totals are very large. This is probably the weakest part of the methodology because of the uncertainties that surround these totals. The intention is that, throughout the document, the point will be emphasised that there is a need to take decisions as early as possible in the assessment.

3) As the European enlargement process continues, the numbers will change. It is not clear how updates to these numbers could be managed.

Cumulated energy demand

List of Cumulated energy demand (CED) examples

Product or service	Units	CED	Reference
		MJ per unit	
Secondary energy			
Electricity from public grid (EU-15)	1 MWh	789	ifeu
Electricity from coal power plant	1 MWh	665	ifeu
Electricity from gas power plant	1 MWh	560	ifeu
Electricity from nuclear power plant	1 MWh	901	ifeu
Electricity from hydroelectric power plant	1 MWh	280	ifeu
Steam from coal firing	1 MWh	344	ifeu
Steam from gas firing	1 MWh	349	ifeu
Fuels, primary energy resources			
Mineral oil (raw)	1 kg	42.6	TREMOD
Diesel	1 kg	42.8	TREMOD
Light fuel oil	1 kg	42.8	TREMOD
Heavy fuel oil	1 kg	40.4	TREMOD
Natural gas (raw)	1 m^3	34	ECOINVENT
Natural gas (purified)	1 m^3	40.3	GEMIS
Coal (medium input mix Europe)	1 kg	29.1	ifeu
Coal (Germany, UK)	1 kg	29.8	ifeu
Coal (South Africa, Australia)	1 kg	26.6	ifeu
Lignite (Germany)	1 kg	9.1	ifeu
Wood chips	1 kg	8.9	ifeu
Rape oil	1 kg	9.3	ifeu
Chemicals, auxiliaries			
Limestone, ground	1 kg	0.053	Patyk
Caustic lime	1 kg	4.18	Patyk
Sodium hydroxide	1 kg	19.9	APME
Ammonia	1 kg	36	Patyk
Methanol	1 kg	42.9	ifeu
Ethanol	1 kg	56	ifeu
Acetone	1 kg	64.3	APME
Glycol	1 kg	64.8	ifeu
Benzene	1 Kg	61.9	APME
Toluene	1 kg	66.2	APME
Metals and construction materials			
Iron	1 kg	14.4	GEMIS
Steel	1 kg	16.3	FFE
Aluminium, primary	1 kg	196	GEMIS
Aluminium, secondary	1 kg	25.8	GEMIS
Copper	1 kg	53	GEMIS
Zinc	1 kg	70.6	GEMIS
Cement	1 kg	4.29	FFE
Concrete	1 kg	0.66	FFE
Plastics			
Polyethylene (HDPE)	1 kg	65.3	APME
Polyproylene	1 kg	71.6	APME
PVC	1 kg	54	APME
PET	1 kg	71.7	APME
Services			
Transport by truck (fully loaded)	1 t/km	0.81	TREMOD
Transport by lorry (fully loaded)	1 t/km	1.44	TREMOD
Incineration of harmful waste (low calorific value)	1 kg	5	ifeu
Disposal of harmful waste in landfills	1 kg	0.22	ifeu
Disposal of inert waste in landfills	1 kg	0.056	ifeu

Annex 14. Table 16.
[34, Fehrenbach H, 2002]

Note: CED is a concept that aggregates the energy consumption in a process, including the energy consumed directly in the process (primary energy consumption) and the energy consumed in producing the raw materials for the process. This can be used to indicate the environmental effects of the process relevant to global warming and acidification. The CED acts as a surrogate for the environmental burden of the product. The definition given in the Verein Deutscher Ingenieure 4600 document "Cumulative Energy Demand – terms, definitions, methods of calculation [16, VDI, 1997]" is: "*The cumulative energy demand (CED) specifies the total sum of primary energy that is expended on production, either directly or causative, in the use and disposal of an economic item (goods and services)*".

<u>Sources</u>

APME – Association of Plastic Manufacturers in Europe: Ecoprofiles of several plastic materials: http://www.apme.org/media/public_documents/20011009_164930/lca_summary.htm

ECOINVENT – Swiss Centre for Life Cycle Inventories, A joint initiative of the ETH domain and Swiss Federal Offices. http://www.ecoinvent.ch/en/

FFE – Forschungsstelle für Energiewirtschaft: http://www.ffe.de/index3.htm

GEMIS – Gesamtemissionsmodell integrierter Systeme: http://www.oeko.de/service/gemis/
ifeu – Institut für Energie- und Umweltforschung, Heidelberg: Updatable and generic Inventory data for energetic systems worked out by original specific data and literature (ECOINVENT, GEMIS, TREMOD, APME)

Patyk et al. : Düngemittel - Energie- und Stoffstrombilanzen; Vieweg-Verlag Umweltwissenschaften; Braunschweig 1997

TREMOD - Transport Emission Estimation Model; software tool worked out by ifeu-Institute for Federal Agency for Environment, Several National Ministries, Association of the German Automotive Industry, Association of the German Petroleum Industry.

Oekopol 2000 – Extract from the Oekopol sector specific database.

Abiotic depletion potentials

The table and text below are reproduced in full from ‘Part 2b of the guide on environmental life cycle assessment’ Leiden University [15, Guinée, 2001] (page 51).

http://www.leidenuniv.nl/cml/lca2/index.html

ADP factors for characterising abiotic resources based on ultimate reserves and extraction rates.

Natural resource	Cas-number	ADP (in kg antimony eq./kg)
actinium (Ac)	7440-34-8	6.33E+13
aluminium (Al)	7429-90-0	1.00E-08
antimony (Sb)	7440-36-0	1
argon (Ar)	7440-37-1	4.71E-07
arsenic (As)	7440-38-2	0.00917
barium (Ba)	7440-39-3	1.06E-10
beryllium (Be)	7440-41-7	3.19E-05
bismuth (Bi)	7440-69-9	0.0731
boron (B)	7440-42-8	0.00467
bromine (Br)	7726-95-6	0.00667
cadmium (Cd)	7440-43-9	0.33
calcium (Ca)	7440-70-2	7.08E-10
cerium (Ce)	7440-45-1	5.32E-09
caesium (Cs)	7440-46-2	1.91E-05
chlorine (Cl)	7782-50-5	4.86E-08
chromium (Cr)	7440-47-0	0.000858
cobalt (Co)	7440-48-4	2.62E-05
copper (Cu)	7440-50-8	0.00194
dysprosium (Dy)	7429-91-6	2.13E-06
erbium (Er)	7440-52-0	2.44E-06
europium (Eu)	7440-53-1	1.33E-05
fluorine (F)	7782-41-4	2.96E-06
gadolinium (Gd)	7440-54-2	6.57E-07
gallium (Ga)	7440-55-3	1.03E-07
germanium (Ge)	7440-56-4	1.47E-06
gold (Au)	7440-57-5	89.5
hafnium (Hf)	7440-58-0	8.67E-07
helium (He)	7440-59-7	148
holmium (Ho)	7440-60-0	1.33E-05
indium (in)	7440-74-6	0.00903
iodine (1)	7553-56-2	0.0427
iridium (Ir)	7439-88-5	32.3
iron (Fe)	7439-89-0	8.43E-08
krypton (Kr)	7439-90-9	20.9
lanthanum (La)	7439-91-0	2.13E-08
lead (Pb)	7439-92-1	0.0135
lithium (Li)	7439-93-2	9.23E-06
lutetium (Lu)	7439-94-3	7.66E-05
magnesium (Mg)	7439-95-4	3.73E-09
manganese (Mn)	7439-96-5	1.38E-05
mercury (Hg)	7439-97-0	0.495
molybdenum (Mo)	7439-98-7	0.0317
neodymium (Nd)	7440-00-0	1.94E-17
neon (Ne)	7440-01-9	0.325
nickel (Ni)	7440-02-0	0.000108
niobium (Nb)	7440-03-1	2.31E-05
osmium (Os)	7440-04-2	14.4
palladium (Pd)	7440-05-3	0.323

Natural resource	Cas-number	ADP (in kg antimony eq./kg)
phosphorus (P)	7723-14-0	8.44E-05
platinum (Pt)	7440-06-4	1.29
polonium (Po)	7440-08-6	4.79E+14
potassium (K)	7440-09-7	3.13E-08
praseodymium (Pr)	7440-10-0	2.85E-07
protactinium (Pa)	-	9.77E+06
radium (Ra)	7440-14-4	2.36E+07
radon (Rn)	-	1.20E+20
rhenium (Re)	7440-15-5	0.766
rhodium (Rh)	7440-16-6	32.3
rubidium (Rb)	7440-17-7	2.36E-09
ruthenium (Ru)	7440-18-8	32.3
samarium (Sm)	7440-19-9	5.32E-07
scandium (Sc)	7440-20-2	3.96E-08
selenium (Se)	7782-49-2	0.475
silicon (Si)	7440-21-3	2.99E-11
silver (Ag)	7440-22-4	1.84
sodium (Na)	7440-23-5	8.24E-11
strontium (Sr)	7440-24-6	1.12E-06
sulphur (S)	7704-34-9	0.000358
tantalum (Ta)	7440-25-7	6.77E-05
tellurium (Te)	13494-80-9	52.8
terbium (Tb)	7440-27-9	2.36E-05
thallium (TI)	7440-28-0	5.05E-05
thorium (Th)	7440-29-1	2.08E-07
thulium (Tm)	7440-30-4	8.31E-05
tin (Sn)	7440-31-5	0.033
titanium (Ti)	7440-32-8	4.40E-08
tungsten (W)	7440-33-7	0.0117
uranium (U)	7440-61-1	0.00287
vanadium (V)	7440-62-2	1.16E-06
xenon (Xe)	7440-63-3	17500
ytterbium (Yb)	7440-64-4	2.13E-06
yttrium (Y)	7440-65-5	3.34E-07
zinc (Zn)	7440-66-6	0.000992
zirconium (Zr)	7440-07-7	1.86E-05
crude oil	8012-95-1	0.0201
natural gas[a]	nvt	0.0187
hard coal	nvt	0.0134
soft coal	nvt	0.00671
fossil energy[b]	nvt	4.81E-04

[a] In kg antimony/m^3 natural gas

[b] In kg antimony/MJ fossil energy

Annex 14. Table 17
[15, Guinée, 2001]

ANNEX 15 - EXAMPLE OF NO_X REDUCTION IN A MUNICIPAL WASTE INCINERATOR

Introduction

As a second example to illustrate the methodologies described in this document, consider alternative options for the control of nitrogen oxide (NO_X) emissions at a fluidised bed municipal waste incinerator [56, Dutton, 2003]. The example is based on a new plant, but could also apply to modifications to existing processes. For the sake of simplicity and availability of data, this example refers to an individual installation, which does not mean that the methodologies are primarily intended for use at the local level. At the BREF sector level, one complication is how to define a representative base case.

The data are based on a real situation and where any assumptions have been made, these are declared in the text. Some of the data have been simplified to clarify the procedures. It is important to bear in mind that the purpose of the example is to illustrate the economic and cross-media methodology, not to determine which incineration/abatement technology represents BAT.

Application of Guideline 1 - Scope and identification of the options

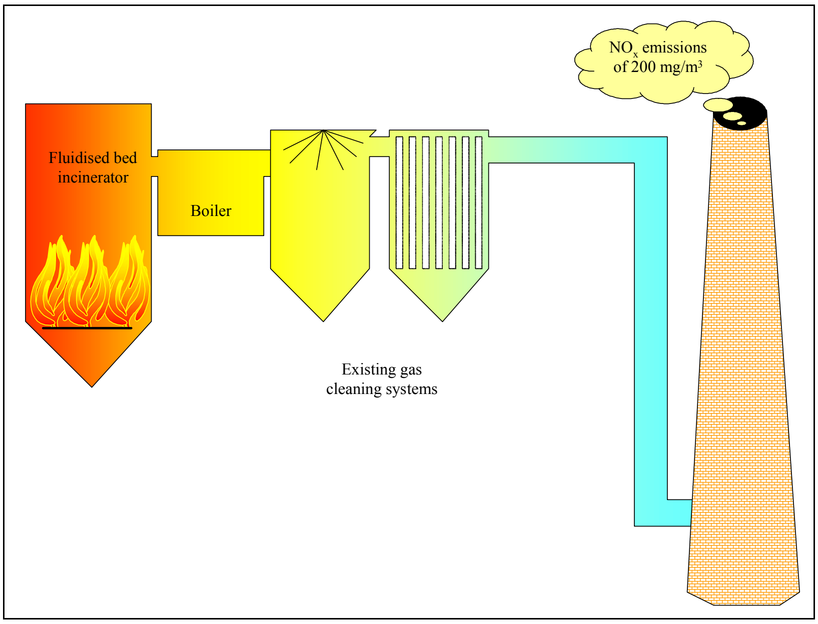
Other activities in the installation, i.e. other than NO_X reduction, (such as waste handling, pretreatment furnace, other abatement equipment or ash handling), result in the same environmental impact for all three options and have been excluded from the scope of the assessment for simplification. It is assumed that the characteristics of the incinerator ash are unaffected by either of the abatement options. Only those emissions that differ between options are presented. The only additional consumptions are ammonia and energy. The efficiency of the use of ammonia is represented by the degree of ‘slip’, i.e. the proportion that is released unreacted, and this is taken into account as an emission to air. The effects of ammonia production however, are not addressed within the system boundary and are not considered to be essential to carry out the assessment.

A fluidised bed furnace will normally achieve a level of NO_X emission around 200 mg/Nm^3 but further control of NO_X emissions is possible with the addition of abatement measures. It should be noted that the incinerator will be subject to the requirements of the Waste Incineration Directive (WID), which specifies 200 mg/Nm^3 as the maximum permissible NO_X emission limit value (ELV) for this type of plant. In the example, further NO_X reduction abatement options are considered against the base case.

The incinerator processes 100000 tonnes of municipal waste per year and is already fitted with semi-dry acid gas abatement equipment. Three options are described below with explanation of the techniques used and using the same system boundaries:

Option 1 - The base case

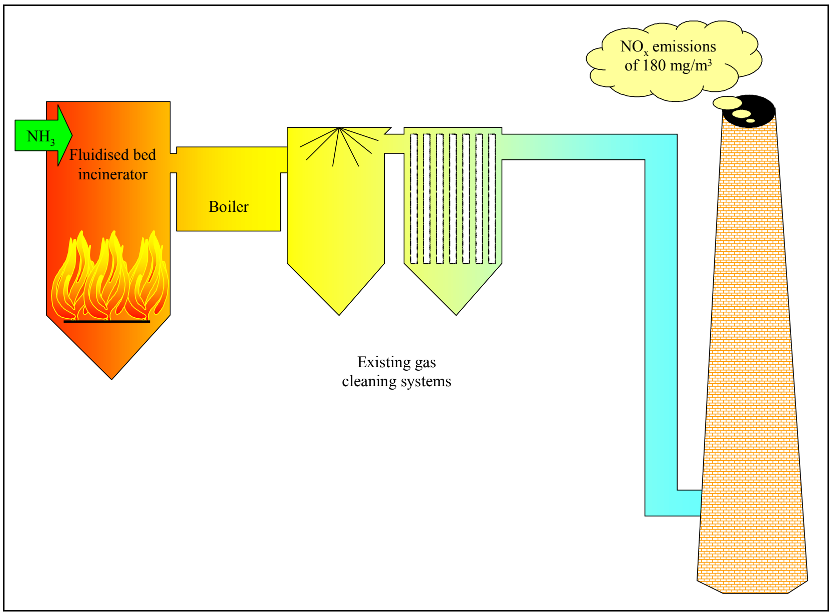
This option is the fluidised bed incinerator, with no additional NO_X abatement.



Option 1 – The base case

Option 2 - Selective non-catalytic reduction (ammonia injection)

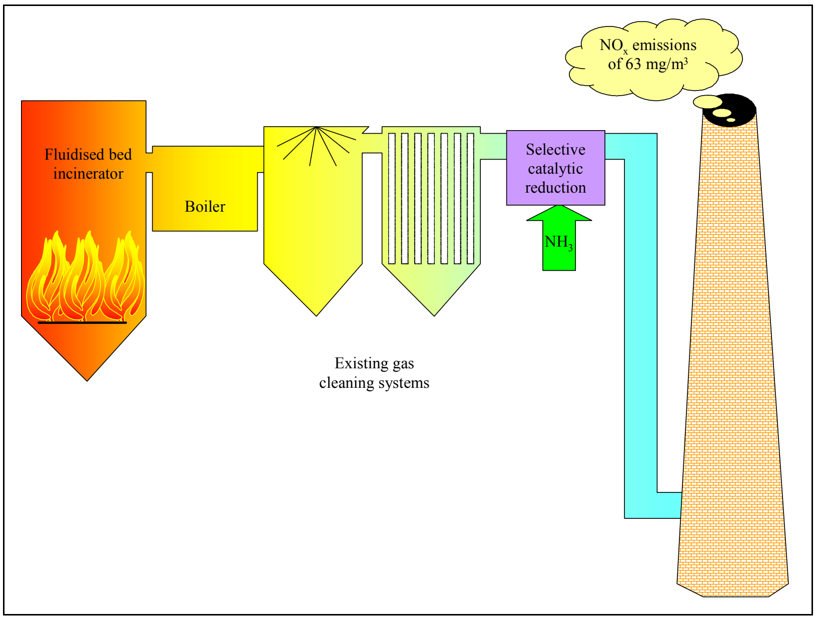
Additional abatement can be realised through injection of ammonia into the furnace. In comparison to the base case, this abatement option typically reduces the concentration of NO_X in the emissions by 10 %.



Option 2 – Selective non-catalytic reduction (ammonia injection)

Option 3 - Selective catalytic reduction (with ammonia injection)

This technique involves a selective catalytic reduction taking place after the existing gas cleaning systems. This technique also includes an injection of ammonia but at the selective catalytic reduction stage instead of into the furnace. The catalyst layer turns NO_X into nitrogen (N_2). This option delivers a reduction of 68.5 % NO_X compared to that of the base case (58.5 % compared to that of Option 2).



Option 3 - Selective catalytic reduction (with ammonia injection)

From this basic information, it can be seen that Option 2 and Option 3 are more costly than the base case and also require additional energy and raw materials (ammonia).

Application of Guideline 2 – Inventory of emissions and energy used

Emissions	**Option 1**			**Option 2**			**Option 3**		
	mg/m³	g/s	t/yr	mg/m³	g/s	t/yr	mg/m³	g/s	t/yr
NO_2	200	19	591	180	17	532	63	6	186
N_2O	5	0.5	1.4	10	0.9	2.7	10	0.9	2.7
NH_3	0	0	0	2	0.2	0.56	3	0.3	0.84

Energy used	**Option 1**			**Option 2**			**Option 3**		
	MWh/yr	GJ/yr	TJ/yr	MWh/yr	GJ/yr	TJ/yr	MWh/yr	GJ/yr	TJ/yr
Heat and power	0	0	0	40	144	0.14	4600	16560	16.56

Annex 15, Table 1

Energy data were provided in MWh/yr for this example, which was converted to GJ/yr using a conversion factor of 3.6 (1 TJ = 1000 GJ).

Conclusion - Option 3 clearly demonstrates superior NO_X (NO_2 + N_2O) abatement. However, the assessment will be taken further as: (a) there is an increase in ammonia emissions, and (b) there remains a concern that Option 3 is too costly, hence it is still not clear at this stage which option is best.

Application of Guideline 3 – Calculation of cross-media effects

Simplification - As a simplification in this example, a quick assessment was made of which environmental themes will be affected by emissions of NO_2 and NH_3. Those environmental themes that are not affected (or are insignificant) can quickly be skipped through in the assessment.

Environmental theme	Relevance	Pollutants
Human toxicity	Relevant	NO_2, NH_3
Global warming	Relevant	N_2O
Aquatic toxicity	Not Relevant	No emissions to water
Acidification	Relevant	NO_2, NH_3
Eutrophication	Relevant	NO_2, NH_3
Ozone depletion	Not Relevant	No emissions of ozone depleting substances
Photochemical ozone creation	Relevant	NO_2

Annex 15, Table 2

Although in this document, the multiplication factors normally refer to kg, the analysis will be carried on in tonnes for simplicity (to convert to kg, it is necessary to multiply by 10^3). An exception is made for human toxicity, for which it is necessary to express the emissions in kg so that they are compatible with the formula used to calculate the toxicity threshold.

Human toxicity

The human toxicity potentials have been calculated as follows (m^3 of air that would theoretically be polluted to its toxicity threshold):

		Option 1		Option 2		Option 3	
	Toxicity threshold ($\mu g/m^3$)	Mass of pollutant released ('000 kg)	Human Toxicity Potential (m^3)	Mass of pollutant released ('000 kg)	Human Toxicity Potential (m^3)	Mass of pollutant released ('000 kg)	Human Toxicity Potential (m^3)
NO_2	40	591	$1.48x10^{13}$	532	$1.33x10^{13}$	186	$0.46x10^{13}$
NH_3	180	0	0	0.56	$3.11x10^{9}$	0.84	$4.67x10^{9}$
Total human toxicity potential (m^3)			**$1.48x10^{13}$**		**$1.33x10^{13}$**		**$0.46x10^{13}$**
Note:	**The mass of pollutant released was converted to kg before calculating the human toxicity potential. From these results, Option 3 is the preferred option as it has the smaller human toxicity potential.**						

Annex 15, Table 3

Global Warming

Global warming potentials in tonnes of CO_2 equivalent released per year were calculated as follows:

		Option 1		Option 2		Option 3	
	Global warming potential (kg CO_2)	Mass of pollutant released ('000 kg)	Global warming potential ('000 kg CO_2)	Mass of pollutant released ('000 kg)	Global warming potential ('000 kg CO_2)	Mass of pollutant released ('000 kg)	Global warming potential ('000 kg CO_2)
N_2O	296	1.4	414.4	2.7	799.2	2.7	799.2
Total GWP ('000 kg CO_2)			**414.4**		**799.2**		**799.2**
From these results, Option 1 is the preferred option as it has the smaller GWP.							

Annex 15, Table 4

Aquatic toxicity

For the three options considered in this example, there are no differences in the releases to water, so there is no need to evaluate the aquatic toxicity.

Acidification

Acidification potentials have been calculated as the sulphur dioxide equivalent in tonnes per year as follows:

		Option 1		Option 2		Option 3	
	Acidification potential (kg SO_2 equivalent)	Mass of pollutant released ('000 kg)	Acidification potential ('000 kg SO_2)	Mass of pollutant released ('000 kg)	Acidification potential ('000 kg SO_2)	Mass of pollutant released ('000 kg)	Acidification potential ('000 kg SO_2)
NH_3	1.6	0	0	0.56	0.9	0.84	1.34
NO_2	0.5	591	295.5	532	266	186	93
Total acidification potential			**295.5**		**266.9**		**94.34**
From these results, Option 3 is the preferred option as it has the smallest acidification effect.							

Annex 15, Table 5

Eutrophication

The eutrophication potential is expressed as the equivalent emission of phosphate ion in tonnes per year. They have been calculated as follows:

		Option 1		Option 2		Option 3	
	Eutrophication potential (kg phosphate ion equivalents)	Mass of pollutant released ('000 kg)	Eutrophication potential ('000 kg phosphate ion equivalents)	Mass of pollutant released ('000 kg)	Eutrophication potential ('000 kg phosphate ion equivalents)	Mass of pollutant released ('000 kg)	Eutrophication potential ('000 kg phosphate ion equivalents)
NH_3	0.35	0	0	0.56	0.2	0.84	0.29
NO_2	0.13	591	76.83	532	69.16	186	24.18
Total eutrophication potential '000 kg PO_4^{3-} equivalents			**76.83**		**69.36**		**24.47**
From these results, Option 3 is the preferred option.							

Annex 15, Table 6

Ozone depletion potential

In this example, there are no relevant emissions of ozone depleting substances.

Photochemical ozone creation potential

Photochemical ozone creation potentials are expressed as the equivalents of ethylene in tonnes per year. They have been calculated as follows:

		Option 1		Option 2		Option 3	
	Photochemical ozone creation potential (POCP) (kg ethylene equivalents)	Mass of pollutant released ('000 kg)	Photochemical ozone creation potential ('000 kg ethylene equivalents)	Mass of pollutant released ('000 kg)	Photochemical ozone creation potential ('000 kg ethylene equivalents)	Mass of pollutant released ('000 kg)	Photochemical ozone creation potential ('000 kg ethylene equivalents)
NO_2	0.028	591	16.55	532	14.9	186	5.21
Total POCP ('000kg ethylene equivalents)			**16.55**		**14.9**		**5.21**
From these results, Option 3 is the preferred option.							

Annex 15, Table 7

Application of Guideline 4 – Interpret the cross-media conflicts

Simple comparison of the environmental themes

Using the information gathered from this example, the following simple comparison can be made.

Environmental effect	Option 1	Option 2	Option 3
Energy	**1**	**2**	**3**
Waste	Not assessed	Not assessed	Not assessed
Human toxicity	**3**	**2**	**1**
Global warming	**1**	**2**	**2**
Aquatic toxicity	Not assessed	Not assessed	Not assessed
Acidification	**3**	**2**	**1**
Eutrophication	**3**	**2**	**1**
Ozone depletion	Not assessed	Not assessed	Not assessed
Photochemical ozone creation	**3**	**2**	**1**

Colour key

1 Preferred Option
2 Mid Performance
3 Worst Performance

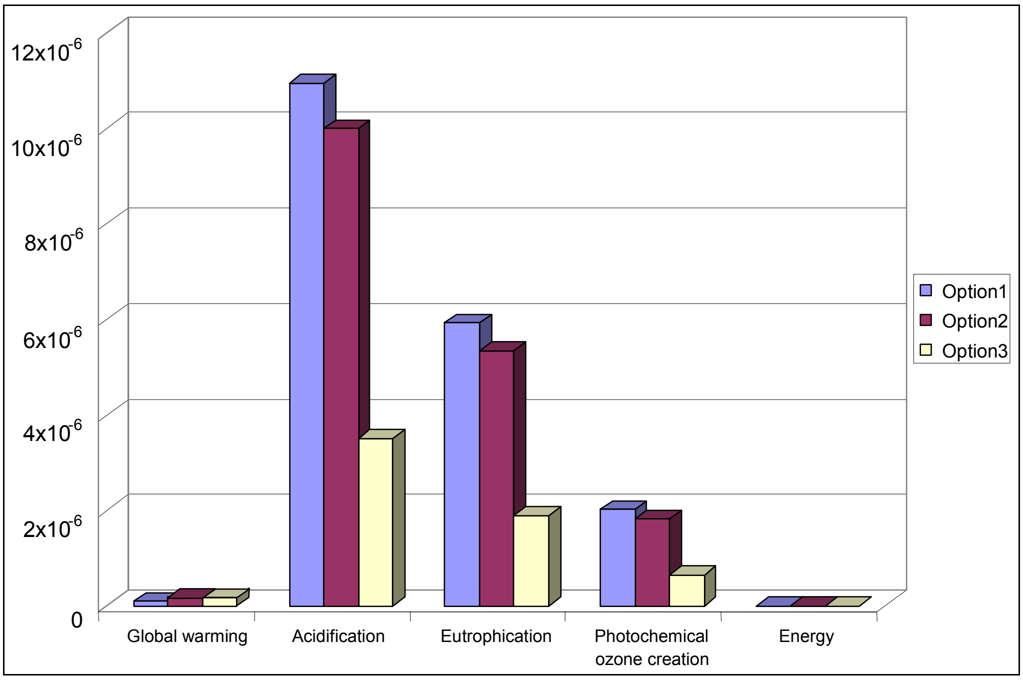
Option 3 is the preferred choice for most of the environmental themes, but it is the worst performer for energy consumption.

Normalisation to European totals

Using the data calculated for this example, comparison of the emissions against total emissions at the European level can be made. (NB all emissions have been converted from tonnes to kg for this part of the assessment.) The figure below presents the results in graphical form which shows that Option 3 appears to have the least overall environmental impact when considering five different themes, noting that waste, aquatic toxicity and ozone depletion potential are not assessed and not included in the figure.

Effect	Option 1		Option 2		Option 3	
	Total	% of European total	Total	% of European total	Total	% of European total
Energy (TJ)	0	0	0.144	0.023 x 10^{-13}	16.56	2.715 x 10^{-13}
Waste	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed
Human toxicity potential (m^3 air)	1.48 x 10^{13}	?	1.33 x 10^{13}	?	0.46 x 10^{13}	?
GWP (kg CO_2 eq)	414.4 x 10^3	0.09 x 10^{-6}	799.2 x 10^3	0.17 x 10^{-6}	799.2 x 10^3	0.17 x 10^{-6}
Aquatic toxicity potential (m^3 of water)	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed
Acidification potential (kg SO_2 eq)	295.5 x 10^3	10.94 x 10^{-6}	266.9 x 10^3	9.89 x 10^{-6}	94.34x10^3	3.49 x 10^{-6}
Eutrophication potential (kg PO_4^{3-} eq)	76.83 x 10^3	5.91 x 10^{-6}	69.36 x 10^3	5.34 x 10^{-6}	24.47 x 10^3	1.88 x 10^{-6}
Ozone depletion potential (CFC-11 eq)	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed
POCP (kg ethylene eq)	16.55 x 10^3	2.02 x 10^{-6}	14.9 x 10^3	1.82 x 10^{-6}	5.21 x 10^3	0.64 x 10^{-6}

Annex 15, Table 8: Emissions normalised against European totals



The three options expressed as a percentage of European totals

Screening local environmental effects

In this example, emissions are screened to identify which emission might need further assessment in the local situation. Using the dilution factors above (1:100000 for air emissions), the following dispersed concentrations were calculated for the three options.

	Option 1		Option 2		Option 3	
	Emission (mg/m^3)	Dispersed concentration (mg/m^3)	Emission (mg/m^3)	Dispersed concentration (mg/m^3)	Emission (mg/m^3)	Dispersed concentration (mg/m^3)
NO_2	200	0.002	180	0.00180	63	0.00063
NH_3	0	0.000	2	0.00002	3	0.00003

Annex 15, Table 9

The environmental quality standards (EQSs) for NO_2 and NH_3 are expressed in µg/m^3, so it is necessary to convert these dispersed concentrations before expressing them as a percentage of the EQS.

Substance	EQS (µg/m^3)	Dispersed concentration as % of EQS		
		Option 1	Option 2	Option 3
NO_2	40	5 %	4.500 %	1.500 %
NH_3	180	-	0.011 %	0.016 %

Annex 15, Table 10

Only the emissions of NO_2 are significant in this respect and are thus likely to need more detailed evaluation in the local situation.

Conclusion on cross-media effects

In the assessment of the environmental effects from the three options considered in this example, Option 3 appears to be preferable for acidification, eutrophication and photochemical ozone creation potential. Option 1 would be preferable for global warming potential and energy. When comparing the values with the European totals, these two latter themes appear to be less significant and, therefore, could carry less weight in an overall assessment. By structuring the assessment in such a way, this can assist subsequent expert judgement in making a trade-off decision.

Costing methodology

The capital and operating costs for this example are presented below. Option 1 is taken as the base case. Costs are presented as additional to the base case. Operating costs are assumed to be constant throughout the years.

Costs (EUR '000)	Option 1	Option 2	Option 3
Total investment cost (EUR '000)	-	185	1475
Total operating costs (EUR '000)/year	-	188	670

Annex 15, Table 11

These costs are used to illustrate the methodologies here, ideally there would have been more information provided to allow for the information to be audited and validated.

Some assumptions have been made in the evaluation of costs. Firstly, the cost of electricity is based on the sale price into the public supply (i.e. not the purchased price). Secondly, the costs include equipment replacement over a 25 year period and for Option 3 catalyst replacement every three years.

Costs are divided between investment costs and operating costs.

Investment costs can be further divided between installation costs (project planning, the cost of land, clean-up, site preparation, buildings, engineering, contractor fees, testing/start-up), pollution control equipment costs (primary control equipment, auxiliary equipment, instrumentation, transport to site, modifications to existing equipment) and other costs (contingency).

Operating costs are divided between energy costs (electricity, petroleum products, natural gas, solid fuel), material and services costs (replacement parts, chemicals, environmental services), labour costs (staff, staff training), fixed costs (insurance, licence fees, emergency provisions, other overheads), cost savings or revenues and subsequent costs.

With the limited information available for this example, it was only possible to calculate the total annual costs.

The annual costs are presented as additional to the base case (Option 1). The assumptions made for this section are 25 years economic lifetime for the plant (based on the furnace replacement) and a 6 % discount rate (based on it being a low risk sector with a low capital cost).

The equivalent annual costs are calculated using the equation:

$$\text{Total annual costs} = C_0\left[\frac{r(1+r)^n}{(1+r)^n-1}\right]+OC$$

Where:

C_0 = the investment cost at year 0 (base year)
r = the discount rate per period (year)
n = the estimated economic lifetime of the equipment in years
OC = the total operating costs.

Therefore,

$$\text{Total annual costs (Option 2)} = 185\times\left[\frac{0.06\times(1+0.06)^{25}}{(1+0.06)^{25}-1}\right]+188 = 202 \text{ (EUR ‘000)}$$

$$\text{Total annual costs (Option 3)} = 1475\times\left[\frac{0.06\times(1+0.06)^{25}}{(1+0.06)^{25}-1}\right]+670 = 785 \text{ (EUR ‘000)}$$

Total annual costs, in addition to the annual costs for Option 1 are:

Option 2 = 202000 EUR
Option 3 = 785000 EUR

Ideally more information would have been provided for the evaluation and validation of these costs, but unfortunately there is no more detail available.

In this example, all costs can be attributed to environmental protection as the techniques are solely aimed at reducing NO_X emissions.

Evaluating the alternatives

In this case, only NO_X is considered in order to simplify the assessment. Therefore, cost effectiveness can be assessed on the basis of costs per tonne of NO_X reduced. In comparison to the base case, the cost effectiveness of Option 2 and Option 3 are as follows.

	Option 2	**Option 3**
Additional annual costs (EUR '000) from the costing methodology	202	785
Reduced NO_X (tonnes) from the cross-media methodology	59 (10 % reduction)	405 (68.5 % reduction)
Cost effectiveness (costs per tonne of NO_X reduced)	**3424**	**1938**
This results in costs of EUR 3424/tonne for option 2 and EUR 1938/tonne for option 3. Therefore, Option 3 is more cost effective.		

Annex 15, Table 12

The external cost from ExternE for NO_X ranges between EUR 1500 and 7100. Both Option 2 and Option 3 fall within this range (at EUR 3424 and EUR 1938 respectively). Whilst a sensitivity analysis could be carried out to more objectively interpret these results, they initially provide an indication to inform expert judgement as to whether the cost effectiveness of the measures meets the criteria of BAT.

Economic viability in the sector

Describing the industry structure

Size and number of plants

The size of installations in the incineration sector tends to be dictated by economy of scale as well as the prevailing waste management strategy within Member States. For example, in the UK most installations serve populations of c. 100000 and capacities mostly lie in the range 50 - 150 kt/year. There are concerns about the cost of applying these NO_X techniques to smaller plants, but enough installations of reasonable capacity exist so this should not constrain the uptake of either technology within the sector in general. Indeed, the techniques already exist in many installations within the EU. This implies that plant size is unlikely to be a major influence on viability.

Technical Characteristics of installations

The sector is highly regulated and has been subject to a succession of specific Directives besides IPPC (most recently the WID), which have required increasingly better environmental performance. In addition, incineration technology and the control techniques described here tend to be well proven in terms of technical availability and performance. Also the techniques can be retrofitted to most types of new and existing incinerator types as they are 'end-of-pipe' abatement techniques. If the techniques need to be retrofitted, there will be a requirement for adequate space. However, the equipment is not unduly large, and many facilities tend to have space allocated for general waste delivery and treatment, which also gives them flexibility to accommodate new equipment. All this suggests that technical characteristics should not be a major factor in determining viability.

Equipment lifetime

The life of on incineration plant is relatively long and secure (for market structure analysis see Section 5.3) and 25 years is a reasonable assumption for the lifetime of a new installation, based on the replacement of the main boiler/furnace equipment. This long-term security of operation improves the confidence that the environmental benefits of investments in environmental protection measures will be maximised over the lifespan of the abatement equipment. Therefore, equipment lifetime is unlikely to be a significant influence on viability.

Barriers to entry or exit

There is already a significant incineration capacity in the EU and demand is increasing due to the move away from landfilling. The trend, at least in the short term, is a predicted growth in incineration capacity, although this will vary between Member States depending on national waste management strategies.

Other industry characteristics

The general, structure of companies operating waste incineration installations varies between Member States. Several operating companies (in the UK at least) have a wider portfolio within waste management or utilities in general, besides operating incineration facilities. In addition, several companies operate installations in more than one Member State.

Conclusion

A general conclusion is that the security of supply, long equipment/plant lifetime and known technology are positive factors which will not adversely impact on viability.

Describing market structure

Market structure for the incineration sector was analysed using the Porter's five forces model.

Rivalry among existing firms

Competition between (municipal waste) incineration facilities is relatively low due to a number of factors. The demand for new incineration capacity outweighs the supply in some Member States (e.g. the UK) mainly due to strong local political resistance which increases the length of the planning process and hence slows down new build plants. In addition, operators of incineration facilities tend to establish relatively long-term, secure contracts with waste collection/disposal authorities for dedicated facilities in specific locations. Finally, the costs of bulk transportation constrain excessive movements between alternative incineration facilities.

The bargaining power of suppliers

Not an issue in this sector.

The bargaining power of customers

Customers and suppliers are assumed to be the same in this sector; namely waste disposal authorities. The relatively low competition described above means that waste disposal authorities do not hold substantial influence over the prices that they pay for disposal. Often with increasing regulatory restriction on landfill and slow developments in the market for recycling, incineration is the only route left available to them. This implies that the incinerator operators will have a reasonable opportunity to pass additional pollution control costs on to their customers in this sector and that the customers will have little choice but to accept the new price. In turn these customers (waste collection and disposal authorities) would then pass such costs on to waste producers (the general public and the manufacturing industry). Such high disposal costs would then encourage diversion of waste to alternative disposal routes, recycling and reduction at source. However, the extent that this would reduce the market for incinerators is limited at present (in the UK at least).

The threat of substitute products or services

There is a growing demand for alternative disposal routes to landfill, driven by the EU Landfill Directive. However, Member States are also encouraging the development of better alternatives to incineration as part of their overall waste management strategies, such as re-use, recycling and recovery facilities. These latter options are influenced by the market for, and the price of, recovered materials and many Member States have found that economic interventions are required to encourage switching away from less desirable options. The rate and degree of substitution is determined by Member States individual waste disposal strategies. In the short term, the substitution rate is countered by a general undercapacity for all the alternatives to landfill and by the fact that incineration still tends to be a lower cost option than the current alternative treatment facilities. There may be eventual substitution for incineration, which could start to affect viability of control techniques, but this will take a longer time frame.

Threat of new entrants
At present there is already undercapacity for incineration facilities, as noted previously, which should encourage new entrants. New entrants are unlikely to affect the viability of existing operators substantially as long-term contracts tend to be established with dedicated, localised facilities.

Conclusion
The overall analysis implies that it should be possible for the costs of pollution control equipment to be passed on to customers relatively easily. In this case, each Member State government will need to assess the effect of imposing costs that they know will largely be passed on to their economy as a whole. The demand for incineration capacity is fairly inelastic to price, although eventually this may change as substitute disposal options (recycling, etc.) become more competitive. The impact of this change in elasticity may also depend on the degree to which incinerator operators control available substitutes as part of their company portfolio.

The above analysis suggests that the current market structure supports the ability of the sector to bear the costs of environmental protection techniques and, therefore, implementing the proposed techniques as BAT should not affect the viability of the sector significantly. In the longer term, this may reduce as substitutes to incineration enter the market.

Resilience

No data was available for the assessment of resilience, but the profit margin of incinerator operators is believed to be relatively high in comparison to other industry sectors such as manufacturing.

Conclusion
The overall analysis of resilience (and other factors described earlier) implies that the costs of pollution control equipment should be able to be readily passed on to customers. The demand for incineration capacity is fairly inelastic to price, although eventually this may change as substitute disposal options (recycling, etc.) become more competitive. This cross-price elasticity may also depend on the degree to which incinerator operators control available substitutes as part of a company portfolio. One additional point to consider concerning the ease which costs can be passed on in this sector is what economic effect this might have at a national level.

Speed of implementation

This aspect is of most importance if implementation of BAT requires major step changes in capital investment over the entire sector, or restructuring of the sector. However, in this incineration sector, the rate of improvement in performance continues to be strongly influenced by EU Incineration Directives. These contain rigid compliance schedules which may be the overriding factor in forthcoming implementation of environmental improvements under the IPPC regime, and have historically led to major rebuild and restructuring of the sector in some Member States (e.g. the UK in 1996). Installations sector-wide will require further investment in techniques to meet at least the NO_X control performance required of the Waste Incineration Directive.

Another factor that should be considered is the operators ability to harmonise implementation within business cycles, such as planned shutdown and maintenance cycles. This may not be a major issue in this example case for the techniques in question as much of the construction can probably be carried out without any disturbance to the normal operation.

Conclusion
The speed of implementation is largely predetermined by the timetable of other Directives.

Conclusion on economic viability

The nature of this sector is such that there is a relatively strong opportunity to pass the costs of environmental controls on to customers, so further investment should not have a major impact on the viability of the sector. Therefore, it would be reasonable to expect the industry to invest in either of the technologies described in Option 2 or Option 3 (i.e. moving away from the base case). As a conclusion from the analysis carried out through this document, Option 3 is more expensive than Option 2. Nevertheless, Option 3 is more cost effective than Option 2 (Option 3 = EUR 1938 per tonne of NO_X reduced, Option 2 = EUR 3424 per tonne of NO_X reduced - calculated in Chapter 4). As Option 3 can also be implemented for a reasonable cost (for the environmental benefit that it will deliver), it is therefore considered to be the preferred option.

These conclusions are clearly related to the input information and, in this example, a NO_X reduction efficiency of 10 % for selective non catalytic reduction (Option 2) may not be typical for this technology. In cases where a higher reduction of 30 % or 50 % might be achieved by applying the same basic technology, the conclusions would be expected to be quite different. Therefore, as said in the introduction to this example, its purpose is to demonstrate application of the economic and cross-media methodologies in this document and the conclusions from the example cannot be used to infer whether a particular technology is generally BAT.