Technical report No 27

Guidelines for defining and documenting data on costs of possible environmental protection measures

Prepared by:
Ian Marlowe and Katie King
(AEA Technology Environment),
Richard Boyd (Metroeconomica),
Rémy Bouscaren (CITEPA) and
Jozef Pacyna (NILU)

Project manager:
Peter Bosch
European Environment Agency

European Environment Agency

Cover design: Rolf Kuchling, EEA

Legal notice

A great deal of additional information on the European Union is available on the Internet.
It can be accessed through the Europa server (http://europa.eu.int)

Printed in Copenhagen

Printed on recycled and chlorine-free bleached paper

European Environment Agency
Kongens Nytorv 6
DK–1050 Copenhagen K
Denmark
Tel: +45 33 36 71 00
Fax: +45 33 36 71 99
E-mail: eea@eea.eu.int

Table of contents

Summary of minimum requirements

The following are minimum requirements; for further guidance see the individual Guidelines.

Guideline 1

Pollutant definitions and assumptions regarding scope of pollutant categories should always be given wherever there is any possibility of ambiguity.

Guideline 2

Sufficient detail of the pollution source should be given to enable comparison with similar processes and to avoid ambiguity.

It is recommended that published source sector classifications should be used wherever possible.

Guideline 3

Sufficient detail of the environmental protection measure should be given to avoid ambiguity, to define its performance characteristics, and to clarify any special circumstances limiting applicability of the measure.

Guideline 4

It is essential that reported costs are defined: what is included, what is excluded, how they have been attributed or apportioned.

It is recommended that costs are also explained in physical terms such as quantity of materials, and as unit prices.

Guideline 5

As a minimum, all data should have a background discussion of the key uncertainties related to the data.

Guideline 6

The year in which the following data apply should always be given:

- cost data;
- currency exchange rates;
- data describing control technologies (efficiency, applicability) and process technologies;
- emissions to the environment.

Guideline 7

The sources and origins of all data should be recorded as precisely as possible so that data may be traced at a later date if necessary.

Guideline 8

As a minimum, any discount/interest rates used should be recorded.

Guideline 9

If cost data are adjusted for inflation or changes in price through time, then the method used should be recorded and any index used should be recorded and referenced.

Guideline 10

If determining annual cost data, the approach which has been used to derive the annual costs should be recorded, along with all underlying assumptions.

Introduction

These Guidelines are published by the European Environment Agency in order to promote good practice in the documenting and use of data on the costs of possible *environmental protection measures* in the context of international data comparisons.

Many users of such cost data have experienced problems when trying to compare data from different sources – in particular, data users do not always know whether comparisons are valid. For example, it is often not clear whether the data are comparable in term of:

the *environmental protection measure(s)* described;
the source(s) to which the measures are applied;
the year(s) when data were valid;
the method(s) by which data have been annualised, inflated or otherwise processed.

These Guidelines aim to establish a common framework and vocabulary for documenting and using data on the costs of possible *environmental protection measures.*

The Guidelines are divided into two parts:

Part 1 contains a set of Guidelines on defining and documenting data for single *environmental protection measures.* These Guidelines aim to define a minimum set of information which will enable data users to understand the contexts in which data comparisons are valid or not valid. These Guidelines are aimed at the following people:

- Managers of technology databases – to help them to design or improve their databases.
- Authors of reports and other studies which draw on cost data – to help them to document the raw data prior to any data processing or modelling.
- Originators of cost data, such as industrial installations, equipment suppliers and engineering consultants – to help them to provide the context for cost data.

The Guidelines presented in Part 1 have been developed through extensive consultation with interested parties throughout Europe. In general broad agreement was achieved for these guidelines, although some differences of opinion were noted.

Part 2 contains Guidelines on some key issues related to processing the raw data. These Guidelines are descriptions of various methods of data processing and contain suggestions for good practice for documentation in instances when these methods are used.

The Agency would like to express its gratitude to all those individuals and organisations who offered their comments and other valued assistance during the development of these Guidelines (see list in Appendix 1). The Agency also

acknowledges the work of its consultants[1] in developing drafts and organising the consultation process.

A number of previous guidelines from other organisations are reviewed in Appendix 2.

[1] AEA Technology Environment; CITEPA; NILU; Metroeconomica.

Part 1: Defining and documenting data for single measures

The following Guidelines 1 to 7 define background information which should be documented with cost data to enable the data to be placed into context. These Guidelines are intended for describing a single *environmental protection measure* applied to a single source, and its associated costs. If more complicated descriptions are required, such as scenarios of combinations of technologies, applied to several sectors, then reference should be made to the draft Guidelines contained in Part 2.

The minimum supporting information considered adequate to describe the cost of an *environmental protection measure* is:

- Details of the *pollution source* to which the measure is applied
- Details of the *environmental protection measure* and its performance characteristics
- How costs are defined
- The year to which data apply
- Indications of data uncertainty
- How pollutants are defined
- References to data sources

Guidelines for each of these seven items follow.

Key to format

Following the title of each Guideline the very basic minimum requirements are highlighted in **bold text**. In most of the Guidelines further explanation and additional recommendations are then given. Words or phrases defined in the Glossary are highlighted in *italic text.*

Three appendices are provided which provide:

Appendix 3: References to internationally recognised definitions of pollutants
Appendix 4: A check-list of cost components
Appendix 5: A summary of Netherlands guidance on attributing costs to environmental protection

Guideline 1: Defining pollutants

Pollutant definitions and assumptions regarding scope of pollutant categories should always be given wherever there is any possibility of ambiguity.

Appendix 3 contains references to internationally recognised definitions of pollutants.

EXAMPLES
'Arisings of waste oils, as defined in the European Directive on the Disposal of Waste Oils (75/439/EEC and Amendment 87/101/EEC).'
'Emissions of Non-Methane Volatile Organic Compounds (NM VOCs) as defined in the 1991 VOC Protocol to the 1979 UNECE Convention on Long-Range Transboundary Air Pollution.'

Guideline 2: Details of pollution source

Sufficient detail of the *pollution source* should be given to enable comparison with similar processes and to avoid ambiguity.

It is recommended that published source sector classifications should be used wherever possible.

Examples of details of *pollution sources* which might be required are:

- size/capacity of the process;
- site-specific properties of the source;
- whether the measure is applied to a new process or is 'retrofit';
- type of process equipment;
- type of input materials used, e.g. grade of fuel used;
- time of operation of the process;
- types of existing *environmental protection measures* and their *efficiencies*;
- age of the installation (if retrofit).

International classifications are preferred to national or other classifications. Documents which define classification schemes should be clearly referenced. Where a study concentrates on specific sub-sector categories within a classification, it should be made clear which emission sources are included in the categories.

Published source sector classifications include:

NACE (Nomenclature générale des activities économiques dans les Communautés européennes), NACE Rev 1, EUROSTAT Publication Series 2e, 1996 (ISBN 92 826 8767 8)

Selected Nomenclature for Air Pollution for Corinair Inventory (SNAP 97)

ISIC (International Standard Industrial Classification of All Economic Activities)

NOSE (Nomenclature Of Sources of Emission), worked by Eurostat and the EFTA. This nomenclature has two dimensions: economic branch and emission generating process.

It is recommended that both NACE and SNAP classifications are used, to provide a proper linkage with both technical and economic statistics.

EXAMPLES

'We report the waste sorting and disposal costs for a car manufacturing plant in western Europe. The plant opened in 1989 and has a capacity of 1100 cars/day. The processes considered are: stamping, welding, painting, assembly, plastics painting, machining, casting. We have considered metal waste, plastic waste, paper/cartons, drums, and palettes; but we have excluded paint sludge and oily waste. The plant is 25 km from its designated landfill site; and 63 km from the nearest licensed drum reconditioning plant.'

'This database of abatement technologies for the Cement Industry deals with the sector covered by NACE code 26500 (NACE Rev 1).'

'This study deals with abatement of emissions from combustion plants >600 MW – a subset of SNAP code 010101 (CORINAIR – SNAP 94 version 1.1).'

Guideline 3: Details of the environmental protection measure

Sufficient detail of the *environmental protection measure* should be given to avoid ambiguity, to define its performance characteristics, and to clarify any special circumstances limiting applicability of the measure.

3.1. Identification of the measure

Ideally the *environmental protection measure* should be identified precisely. When this is not possible, the measure should be identified as a generic category. Examples of categories are:

- Housekeeping-type measure
  e.g. improved maintenance.

- Process modification
  e.g. minor changes in production processes to reduce waste arising.

- Integrated measure
  e.g. major changes or replacements to processes or plants to optimise performance

- Product reformulation
  e.g. solvent-borne paints reformulated for water-borne paints.

- End-of-pipe technology
  e.g. incineration, adsorption, filter beds, membrane technology.

- Non-technical measure

e.g. organisational changes, lifestyle changes, bans on products / materials, taxes.
(a reminder – these guidelines focus on *technical measures*)

3.2. Performance characteristics of the measure

The *efficiency* of a given *environmental protection measure* should be stated for the pollutant(s) under consideration, as well as the operating conditions and year for which that *efficiency* applies. The reason for any limitations or enhancements to performance should be stated, such as:

- age of abatement equipment;
- enhanced/limited performance when combined with pre-existing measure(s);
- monitoring or control regime;
- degree of operator training/qualification required.

Efficiencies of *environmental protection measures* are often expressed as a percentage, for example 'an incinerator reduces organic emissions by over 95%'. This is not always helpful as we do not know what the uncontrolled emissions were. It is recommended to record *efficiencies* in one of two ways:

- a *base case* emission or *emission factor* for the installation PLUS a percentage *efficiency* for the measure, for example 'for a process emitting over 1 gram of solvent per m^3 of exhaust air an incinerator has a solvent destruction *efficiency* of at least 95%'

OR

- an emission or *emission factor* for the installation after implementation of the measure, for example 'for a solvent emitting process fitted with an incinerator the emission is normally 50 mg of solvent per m^3 exhaust air or less'.

(See also the recommended use of the '*base case*' in defining the costs of the measure -Guideline 4).

3.3. Lifetime of the measure

The anticipated lifetime of the measure should be stated, both as the *technical life* and as the *economic life*.

3.4. Side-effects

Any *side-effects* of the measure should at least be described, and ideally quantified, notably its effects on other pollutants and environmental media. For example the measure might be intended to reduce air pollution but a *side-effect* is increased water pollution.

3.5. Availability of the measure in the market

For measures not widely available on the market throughout the world the state of development should be indicated. If possible the date at which the measure will become widely available should be recorded. For example this guideline would apply to:

- measures that are still at design or trial stage;

- measures that are only available in a given geographical area.

3.6. Applicability of the measure

Describe any technical or non-technical characteristics that may influence the application of the *environmental protection measure* to the designated emission source or that may limit the time horizon of the application. Examples are:

'This technology is not normally considered economically viable at water flow rates of less than 2 m^3 per hour'.

'This measure has been successfully trialled in the laboratory and should become available commercially in 2-3 years but it is not yet known whether the inclusion of a radioactive source will inhibit its uptake'.

EXAMPLES

'Good housekeeping measures are described for minimising glass waste arisings.'

'Costs are presented for Acme carbon adsorption units. The units are available in 0.5 m^3, 2 m^3, 5 m^3 and 10 m^3 capacities (volume of packing). The data presented are for units retrofitted to VOC waste streams in the printing sector. In all cases measured emissions after the unit were less than 150 mgC/m^3.'

'The equipment is estimated to have an operational lifetime of 8 to 12 years, depending on the pH of the effluent – maximum lifetime is achieved at pH > 7. The *efficiency* is inhibited at pH < 4. The costs presented were discounted over a 5-year period.'

'It should be remembered that replacement of the solvent-based stripper by mechanical stripping using CO_2 pellets leads to a small greenhouse gas contribution.'

'The membranes are undergoing pilot trials at one refinery, due for completion in 18 months. It is unlikely that they will be commercially available for at least 30 months.'

Guideline 4: Defining the costs of the environmental protection measure

It is essential that reported costs are defined: what is included, what is excluded, how they have been attributed or apportioned.

It is recommended that costs are also explained in physical terms such as quantity of materials, and as unit prices.

4.1. Reporting costs as actual expenditure

As far as possible, it is recommended that all cost data should be documented in full in the year in which the actual expenditure is incurred, even if the data are subsequently adjusted to take account of time (such as by using *discount/interest rates*). This is to enable other modellers to manipulate the data in different ways.

Guidance on the use of *discount/interest rates*, and on how to take account of *inflation*, is given in Part 2 of the guidelines.

4.2. Reporting costs as 'additional'

All costs should be measured in relation to an alternative. The alternative most commonly employed is a projection of the existing situation, i.e. the situation in which the *environmental protection measure* has not been installed. This is usually called the '*base case*'. Therefore, only *additional costs* actually incurred relative to the '*base case*' should be included in the reported cost data. (See also the recommended use of the '*base case*' in defining the *efficiency* of the measure – Guideline 3).

4.3. Cost components

Studies should explicitly state which cost components have been included in the reported cost data. As a minimum, the total *investment expenditure* and total annual *operating/maintenance costs* should be reported separately.

Further guidance on more detailed cost components which might be reported is given in Appendix 4.

4.4. Reporting physical data and prices

It is helpful to future users of cost data to understand the physical materials which the costs refer to, and their prices. Taking electricity for example, it is helpful to know the quantity of electricity used and its price, as well as the cost: 'The electricity cost is 4,000 ECU per year (100,000 kilowatt-hours per year at a price of 0.04 ECU per kilowatt-hour)'.

4.5. Attributing costs to environmental protection

Reported cost data should distinguish between resources consumed by measures whose explicit purpose is to reduce or prevent emissions of pollutants, and measures that may be implemented purely for commercial reasons, even withstanding the environmental benefit. The latter might include *investment expenditure* in energy conservation or waste minimisation technologies, which yield 'recovery credits' which more than offset the resource costs. In general, end-of-pipe measures tend to serve no other purpose than to reduce or prevent emissions of pollutants; all resource costs may therefore be attributed to environmental protection. In contrast, process-integrated measures 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. Further guidance on how to attribute the resource costs of an abatement measure solely to environmental protection is provided in VROM (1994). A revised version of these guidelines was recently published in Dutch (VROM, 1998), however this is not yet available in English. The VROM guidance is summarised in Appendix 5.

4.6. Apportioning costs between pollutants

Where the costs associated with an *environmental protection measure* have been apportioned between two or more controlled pollutants, the method of apportionment should be described.

4.7. Excluding indirect costs

The reported cost data should only relate to *direct costs*; *indirect costs* should be excluded from the cost data.

4.8. Taxes and subsidies

All taxes and subsidies should be identified where possible and reported separately – for example purchase taxes, property taxes and taxes on fuel or other operating materials. As a minimum, VAT should be reported separately.

4.9. Benefits and avoided costs

Where *environmental protection measures* produce non-environmental benefits, *revenues* or *avoided costs*, these should be reported separately from *investment expenditures* and *operating and maintenance costs.*

It is recommended that non-environmental benefits, *revenues* or *avoided costs* are also stated in physical terms, such as:

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

Further guidance on non-environmental benefits, *revenues* or *avoided costs* which might be reported is given in Appendix 4.

4.10. A caution: cost data have a 'shelf-life'!

It should be remembered that costs and prices are not fixed for ever. For example, the unit price of a measure often falls as it changes from an experimental measure to a mass-produced measure. Therefore it is recommended to use the most recent valid data available.

4.11. A second caution – ageing equipment

It should be remembered that old equipment can sometimes have a lower *efficiency* and higher maintenance costs than new equipment.

EXAMPLES

'All equipment was purchased and installed in 1997. The *operating/maintenance costs* refer to the 12 months from May 1997 during which time the plant was operating under normal conditions.

Purchase costs taken into account were for equipment not required in the uncontrolled '*base case*':

- the adsorption unit itself (11 000 ECU);
- 10 m of additional ducting, 15 cm internal diameter (15 ECU per meter);
- flow meter (200 ECU).

Hence the total *investment expenditure* was 11 350 ECU (in 1997 prices). VAT (additional 15% on purchased equipment) is reported separately below.

Operating/maintenance costs comprise:

- replacement of adsorbent (1300 kg at 5 ECU/kg) after 6 months (i.e. bi-annually);
- staff time (2 hours per week, 52 weeks per year; at 10 ECU/hr).

The costs of the steam have been excluded as an equivalent amount was required in the previous process. Hence total *operating and maintenance costs* amount to 14,040 ECU per year (in 1997 prices).'

'Because the effluent treatment plant removes both BOD and heavy metals, some apportionment of the costs between these pollutants should be made. As the impacts, risks and environmental benefits of these pollutants are complex and difficult to compare, we have made a simple allocation of 50% of the costs between each pollutant type. The BOD removal costs in the table below therefore represent half the expenditure.'

'It is estimated that the measures described will reduce waste packaging by 12 kg per tonne of product.'

Guideline 5: Documenting data uncertainty

As a minimum, all data should have a background discussion of the key uncertainties related to the data.

A large number of uncertainties are associated with cost, performance and other data for most *environmental protection measures*. These uncertainties are partly because there is simply a lack of available information and partly because the key assumptions behind the cost data are not always precisely definable.

5.1. Data ranges

Quantitative ranges should be provided for all data if possible.

5.2. Data quality rating systems

Data quality rating systems have been used for emission estimates to give a qualitative indication of the reliability of data estimates. This approach has been extended to a generic data quality rating system.

The following data quality system is recommended for all estimated data:

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.

An example of a data quality rating system is that used in the EMEP/CORINAIR Guidebook where emission estimates are given a data quality from A to E according to defined criteria. Reference: EMEP/CORINAIR Guidebook (1998) Atmospheric Emission Inventory Guidebook. Second edition. Available from S Richardson (Editor), AEA Technology Environment, Culham, Abingdon, OX14 3DB, United Kingdom. Also available at http://www.eea.dk/aegb/default.htm.

EXAMPLES

'Emissions of HCl from MSW incinerators in the European Union in 1995 are estimated to be 3.6 kt/yr. This estimate has a data quality E (data quality system defined in EMEP/CORINAIR 1998).

The above figure of 3.6 kt/yr is a best estimate. The potential range in emissions of HCl is estimated to be 1.1 - 18.1 kt/yr.'

Guideline 6: Year to which data apply

The year in which the following data apply should always be given:

- cost data;
- currency exchange rates;
- data describing control technologies (*efficiency*, applicability) and process technologies;
- emissions to the environment.

EXAMPLES

Cost data
'The capital equipment cost 100 000 ECU in 1992.'
'The energy savings of the measure were estimated using the price of North Sea gas in 1996.'
'The abatement equipment cost 10 000 ECU to install in 1997 prices.'

Currency exchange rates
'It is assumed that 1 ECU was equivalent to 1.87 DM throughout 1995.'
'For currency conversion we have used the spot rate £1 = 3.1171 Dfl at 12:00 noon on 9 December 1998.'
'An exchange rate of 1 FF = 0.15 ECU, as of 2 April 1998, was used.'

Technology descriptions
'The control measure retrofitted to the waste water treatment plant had a BOD removal *efficiency* of 95 % in 1990.'
'The applicability of FGD to the MSW incineration sector was 50% in 1994'.
'Fluidised bed combustion technology was used in 80% of the sector in 1992'.

Emissions to the environment
'MSW arisings were 15 Mt in 1996.'
'Total Benzo[a]pyrene emissions were 18.5 tonnes in 1995.'

Guideline 7: References to data sources

The sources and origins of all data should be recorded as precisely as possible so that data may be traced at a later date if necessary.

If the data source is a published report or database then a standard bibliography will normally suffice.

If the data source is a verbal or other undocumented communication, this should be clearly stated.

It is recommended that the origin of the data is also explained. For example:

- performance data might be based on engineering judgement, on limited laboratory trials, or on field measurements in many situations;
- cost data might be based on engineering judgement or on supplier's prices.

EXAMPLES

'Emissions of HCl from MSW incinerators in the European Union in 1995 are estimated to be 3.6 kt.

The assumptions for this calculation are:

- *activity statistic* of 36.2 Mt of MSW incinerated in the EU in 1995 (Quass et al., 1997);
- an *emission factor* of 0.1 kg HCl / tonne of MSW (EMEP/CORINAIR 1998);
- the *emission factor* represents plant with spray dryer and fabric filter abatement technology.

References for calculation:

Quass and Fermann, 'Identification of Relevant Industrial Sources of Dioxins and Furans in Europe.' Materialien No. 43, Landesumweltamt Nordrhein-Westfalen, ISBN 0947-5206 (1997).

EMEP/CORINAIR, 'Atmospheric Emission Inventory Guidebook', Second edition (1998). Available from S Richardson (Editor), National Environmental Technology Centre, Culham, Abingdon, Oxfordshire, OX14 3DB. Also available at http://www.eea.dk/aegb/default.htm.'

Part 2: Guidelines for data processing

The Guidelines contained in Part 2 are descriptions of various methods of data processing and contain suggestions for good practice for documentation in instances when these methods are used:

- Dealing with *inflation*
- Calculating annual costs
- *Discount/interest rates*
- Additional issues relating to the implementation of costs data

It is strongly recommended that, where data are to be processed, the raw unprocessed data are first documented as described in Part 1.

Guideline 8: Discount/interest rates

As a minimum, any *discount/interest rates* used should be recorded.

Discounting is the mechanism whereby costs (and benefits) that accrue at different points in time are weighted to facilitate comparison. It is also one of the more misunderstood concepts in economic analysis.

There are two main justifications for *discounting*:

- the productivity of capital rationale, which says we should discount the future at a *discount rate* based on the *opportunity cost of capital*;

- the *time preference* rationale, which says that we should value the present more than the future because people simply prefer benefits now as opposed to later.

When annual cost data is reported, often not enough detail is provided relating to the *discount/interest rate* used to compute the annual costs, or the assumptions underlying the choice of rate. This is problematic for two reasons:

- it makes reliable comparisons with other annual cost data difficult to make; and

- it makes it difficult to re-work the reported data to suit the requirements of another study.

In some cases users may be required to compute annual costs from raw data, but may not be familiar with the principles of *discounting*. To minimise computational errors and the misuse of *discount/interest rates*, it is therefore important that users understand the options available regarding the choice of *discount/interest rate*.

Problems may also arise if consistency is not maintained between the use of after-tax and pre-tax, *nominal* and *real* cost data, and after-tax and pre-tax, *nominal* and *real discount/interest rates*.

Where *discount/interest rates* are used:

- The *discount/interest rate* used should be stated. [Note: It is important to ensure that a '*real*' *discount/interest rate* is used.]

- The basis of the rate used should be explained, i.e. whether it is based on the *opportunity cost of capital*, the cost of interest bearing debt, the social discount rate; and any underlying assumptions.

- If the actual rate used 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, e.g. for variations in lender risk between sectors, then these modifications 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/interest rates* should be applied before any tax considerations, i.e. a pre-tax rate should be applied to pre-tax cost data.

EXAMPLES

'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 annum. 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. This approach is recommended by VROM (1994).'

Note: The *real rate* = [(1 + *nominal rate*) / (1 + *inflation rate*)] - 1]

Guideline 9: Dealing with inflation

If cost data are adjusted for *inflation* or changes in price through time, then the method used should be recorded and any index used should be recorded and referenced.

The *general price level*, and the *relative prices* of goods and services, change with time. This implies that the cost of *environmental protection measures* will also change over time, which presents two potential problems for environmental costing studies:

1. Expressing the original cost data in the price level of a common year (typically the *base year*)

Cost data for different *environmental protection measures* may 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 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 which the data is an input. For example, a reference may quote the cost of a piece of pollution control equipment as 1.5 million DM in 1992, yet the *base year* of the study for which the data is required might be 1995. Assuming prices have changed over the intervening period, if the quoted cost is used directly in the study, the results will be an underestimate. Equally, if the *base year* is 1990 and the quoted cost is used directly, the results will be an overestimate.

In existing studies it is not always clear whether the cost data is expressed in the 'price level' pertaining to the *base year* of the study for which it is needed. Moreover, the year to which the original cost data applies is not always stated, thereby making price adjustments impossible. (Although this problem is addressed by Guideline 6.) Where price adjustments have been made, the *price index* used to make the adjustments is not always stated. It is therefore difficult to identify whether the adjusted cost data are '*real*' or '*nominal*'.

2. Accounting for price changes over the lifetime of the measure

Operating and maintenance costs may vary over the useful life of an *environmental protection measure*. There are different ways in which this can be handled by the analyst, for example, it may be assumed that all costs remain constant in *real* terms over the life of the measure. It is not always clear, however, what assumptions if any, have been made regarding the treatment of *inflationary/ deflationary* effects. The absence of clearly stated assumptions makes it difficult to make reliable annual cost comparisons.

This guideline is divided into two parts. To facilitate reliable comparison between different abatement measures, the first part offers guidance on how to express the raw cost data in the prices of a common year. The second part provides guidance on accounting for price changes over the lifetime of abatement measures. Therefore, the second part of this guideline is more relevant to situations where the raw cost data is being processed: in scenario studies for example.

9.1. Expressing the original cost data on an equivalent price basis

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, whether it be in '*nominal*' or '*real*' terms. Moreover, if the cost data is to serve as an input into some form of economic analysis, it is advisable that this 'common' year corresponds to the '*base*' *year* of the analysis.

A general 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.

Step 1:

price adjuster
equals
appropriate *price index* for the '*base*' *year* of the analysis
divided by
appropriate *price index* for the year to which the raw cost data pertains

Step 2:

adjusted cost data
equals
original cost data
multiplied by
price adjuster

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 stated. Furthermore, it is important to identify whether the adjusted cost data is expressed in '*nominal*' or '*real*' terms. If '*nominal*' cost data has been converted to '*real*' cost data, then the *price deflator* (e.g. GDP deflator) used to make this conversion should be provided. Some simple relationships for converting between '*nominal*' and '*real*' prices are provided below.

- '*Nominal*' price series in a given year divided by the *price deflator* for that year (x 100) equals the '*real*' price series.

- '*Real*' price series in a given year times the *price deflator* for that year (÷ 100) equals the '*nominal'* price series.

- '*Nominal*' price series in a given year divided by the '*real*' price series in that year (x 100) equals the *price deflator*.

Any *price index* used should be recorded and referenced. An important source of European price indices is indicated below, after the Examples box.

9.2. Accounting for price changes over the lifetime of the measure

The price of individual cost components (specifically energy, materials, and labour) may vary over the useful life of an *environmental protection measure*, either as a result of general price *inflation* or a change in their *relative prices*.

It is recommended that the cost of *environmental protection measures* are valued in '*real*' prices in economic studies (e.g. cost-effectiveness analyses, compliance cost assessments). These are usually the prices prevailing at the '*base*' *year* of the study. The use of '*real*' prices is advocated because they are simpler to use, it is easier to make inter-temporal comparisons using constant prices, and the results are not influenced by the underlying rate of *inflation*.

The use of '*real*' cost data presumes that the price of all cost components changes at the same rate as the *general price level*, so that price relativities are constant. If the *relative price* of a cost component is expected to change over the life of the measure, however, then this change in its *real* value should be allowed for when computing annual costs, and justification for the forecast price movements should also be given. Otherwise, it is implicitly assumed that all cost data remain constant in *real* terms.

EXAMPLES

Example 1: Expressing the original cost data on an equivalent price basis.

Consider a pollution control system with annual energy savings of £5,620 recorded at *current prices* in 1991, i.e. it saves 1 GWh of heavy fuel oil (HFO) per year at a price of 0.562 pence per kWh. Now suppose that it is necessary to express the cost data for this control system in 1995 prices - because 1995 is the base year for a cost study. The required adjustment is shown below. The annual energy savings at *current prices* in 1995 are £7,310 (i.e. 1 GWh x 0.731 p/kWh); in *real* terms, the annual energy savings are £6,500 (i.e. 1 GWh x 0.650 p/kWh).

Step 1:

price adjuster: 1.301
equals
current price index (HFO) for UK industrial sector (1995): 114.2
divided by
current price index (HFO) for UK industrial sector (1991): 87.8

Step 2:

'*nominal*' price of HFO in 1995 prices: 0.731 p/kWh
equals
'*nominal*' price of HFO in 1991 prices: 0.562 p/kWh
multiplied by
price adjuster: 1.301

Recall: '*Nominal*' price series in a given year divided by the *price deflator* in that year (x 100) equals the '*real*' price series. Equally, 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:

'*real*' price of HFO in 1995: 0.650 p/kWh
equals
'*nominal*' price of HFO in 1995: 0.731 p/kWh
divided by
change in UK GDP deflator from 1991 to 1995: (119.8 ÷ 106.5).

The last step above is equivalent to:

one plus the inflation rate between 1991 and 1995: 1.125
equals
seasonally adjusted GDP deflator at market prices (1995): 119.8
divided by
seasonally adjusted GDP deflator at market prices (1991): 106.5.

Example 2: Accounting for price changes over the lifetime of the measure

Assume that the pollution control system used in the above example, is one measure being considered in a cost-effectiveness study. Furthermore, the '*base*' *year* of the study is 1995. Two examples of how movements in the price of heavy fuel oil over the life of the control system may be handled are presented below.

1. Energy savings over the life of the control system are assumed to remain constant in *real* terms, i.e. £6,100 per year. Possible accompanying statements include:

   'The *relative price* of HFO is not anticipated to change over the life of the control system.'

   'Current HFO prices are forecast to rise on average by 2.5 per cent per year for the next five years, and the underlying rate of *inflation* is forecast to remain at 2.5 per cent per year between 1996 and 2001.'

   'Both forecasts were obtained from The Office of Electricity Regulation and the Treasury.'

2. Energy savings over the life of the control system are expected to increase in *real* terms by 2.64 per cent per year, i.e. the annual energy savings of the system in *real* terms are £6,100 in the first year of operation, £6,261 in the second year, £6,426 in the third year, and so on. Possible accompanying statements include:

   'The *relative price* of HFO is anticipated to increase at a rate of 2.64 per cent per year over the life of the control system.'

   'Current HFO prices are forecast to rise on average by 5.0 per cent per year for the next five years.'

   'The underlying rate of inflation is forecast to remain at 2.3 per cent per year between 1996 and 2001.'

   'Both forecasts were obtained from The Office of Electricity Regulation and the Treasury.'

EUROPEAN PRICE INDICES

The best summary 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 ECU and national currencies)

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

6) Consumer Price Index:

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

7) Exchange Rates:

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

Note: items 6) and 7) are also available in more detail from the monthly publication 'ECUSTAT'

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/eurostat.html).

Guideline 10: Calculating annual costs

If determining annual cost data, the approach which has been used to derive the annual costs should be recorded, along with all underlying assumptions.

The costs of *environmental protection measures* may need to be presented such that various measures with different economic lives can be compared. This is typically accomplished by converting all the *cash flows* accruing over the life of a measure to an *equivalent annual cost*, or simply, an annual cost[2].

There are essentially two approaches given in the literature for calculating the *total annual cost* of an investment (in this case an *environmental protection measure*):

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

2. *Total annual cost* = *annual capital cost* (yearly *depreciation charge* plus average *interest* cost per year) + net annual *operating and maintenance costs*.

This guideline is only applicable to situations where the raw cost data is being processed, for example to serve as an input to cost-effectiveness analyses or some other form of economic analyses.

These guidelines deal with the *real* economic costs of *environmental protection measures* (i.e. the *opportunity cost of resource use*) as opposed to the financial costs. In economic terms the capital costs of an *environmental protection measure* are incurred when the measure is actually purchased and installed. *Interest* paid on funds borrowed by the investing agency represent a financial cost to the investing agency; it does not represent the economic cost of capital inputs because it is simply a transfer payment from the investor to the lender. Likewise, *depreciation* allowances are also financial costs that do not, in general, correspond with economic cost. They are purely an accounting convention.

Where it is necessary to calculate annual costs, it is therefore recommended that a discounted cash flow technique is used, specifically:

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

The *discounting* procedure captures the *opportunity cost of the capital* resources tied up in the abatement measure.

When reporting annual cost data, the approach which has been used to derive the annual costs should be given, along with all underlying assumptions, including:

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

---

[2] Sometimes the terms 'equivalent uniform annual cost', 'equivalent uniform annual net disbursements', 'annual worth-cost', or 'annualised cost' are used instead of annual costs.

If some variation of the recommended discounted cash flow approach or an approach based on *depreciation charges* plus average *interest* costs is adopted, then details of the variation should also be provided.

EXAMPLES

The example presented below is based on the following data set:

Investment Expenditure:	250,000 ecu
Pollution control equipment	187,500 ecu
Direct installation	62,500 ecu
Net *Operating/Maintenance Costs*:	75,000 ecu
Energy	20,000 ecu
Labour	50,000 ecu
Materials	5,000 ecu
Revenue/Avoided Costs	0 ecu
Equipment lifetime	5 years
Discount rate	8%

All cost data are expressed in 1998 prices, which is also the *base year* for the study. To reduce the amount of notation used, the pollution control equipment is assumed to have no resale or salvage value.

Example 1: Discounted Cash Flow Approach

The recommended approach to calculating *total annual costs* involves first determining the *present value* total cost of the *environmental protection measure*, and then applying an appropriate *capital recovery factor*. The *present value* total cost (PVC) of an investment is computed as follows:

$$PVC = \sum_{t=0}^{n} \frac{(C_t + OC_t)}{(1+r)^t}$$

where

C_t … total *investment expenditure* on the abatement equipment in period t (the period t is typically one year);

OC_t … total *operating and maintenance costs* during period t;

r … the *discount (interest) rate* per period.

n … the estimated useful lifetime of the equipment in years.

The *present value* of the total cost stream of the pollution control equipment is 549,446 ecu; the calculations are summarised in the table below. This represents the total cost to be recovered in equal annual amounts (denoted by A_t) over the lifetime of the equipment. Therefore, the *total annual cost* of the pollution control equipment is given by

$$A_t = PVC\left[\frac{r(1+r)^n}{(1+r)^n - 1}\right] = 549{,}446ecu\left[\frac{0.08(1.08)^5}{(1.08)^5 - 1}\right] = 549{,}446ecu\,(0.2505) = 137{,}613ecu$$

.
where

$$\left[\frac{r(1+r)^n}{(1+r)^n - 1}\right] \ldots$$ *capital recovery factor.*

Example 2: Calculating the *present value* total cost of the *environmental protection measure* (ecu)

Year	0	1	2	3	4	5
1 **Discount factor**[1]	1.000	0.9259	0.8573	0.7938	0.7350	0.6806
2 **Investment Expenditure** (a+b):	250,000	-	-	-	-	-
a Equipment cost	187,500	-	-	-	-	-
b Installation costs	62,500	-	-	-	-	-
3 **Operating and Maintenance Costs** (a+b+c-d):	-	75,000	75,000	75,000	75,000	75,000
a Energy	-	20,000	20,000	20,000	20,000	20,000
b Labour	-	50,000	50,000	50,000	50,000	50,000
c Materials	-	5,000	5,000	5,000	5,000	5,000
d Revenue/Avoided Costs	-	-	-	-	-	-
4 **Total cost** (2+3)	250,000	75,000	75,000	75,000	75,000	75,000
5 **Discounted total cost** (1*4)	250,000	69,443	64,298	59,535	55,125	51,045
6 **PVC** (sum line 5)	549,446					

Notes: [1] The *discount factor* is given by $1/(1+r)^t$.

Alternatively, if the annual *operating and maintenance costs* are expected to remain constant in *real* terms over the useful lifetime of the pollution control equipment, then the *total annual cost* of the equipment may be determined by first computing the *annual capital cost* of the equipment using the *capital recovery factor*, and then adding to this the annual *operating and maintenance costs*. Therefore

$$A_t = C_0\left[\frac{r(1+r)^n}{(1+r)^n - 1}\right] = 250{,}000ecu\left[\frac{0.08(1.08)^5}{(1.08)^5 - 1}\right] = 250{,}000ecu(0.2505) = 62{,}614ecu$$

.
In this case, the *total annual cost* of the pollution control equipment should read:

***Annual Capital Cost*:**		
Annual recovered capital	+62,614 ecu	
Sub-total	=	+62,614 ecu
Net *Operating and Maintenance Costs*:		
Energy	+20,000 ecu	
Labour	+50,000 ecu	
Materials	+5,000 ecu	
Revenue/Avoided Costs	-0 ecu	
Sub-total	=	+75,000 ecu
Total Annual Cost		=137,614 ecu

Expressed in general terms, the *total annual cost* of a pollution control measure may be calculated with the use of a *capital recovery factor* in one of two ways:

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

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

Note: The latter approach offers greater flexibility in that it provides a framework for explicitly accounting for the effects of *real* price escalation on the various *operating/maintenance cost* components.

Examples of how to report *total annual costs*

Approach used:

'*total annual cost* were computed by amortising the *present value* of the total cost stream'

Underlying assumptions:

'the equipment was assumed to have a technical lifetime of 8 years'

'the total cost stream was *discounted* at a *real* rate of 10 per cent'

'the pollution control equipment cost 250,000 ecu in 1998.

'the capital equipment was written-off over 15 years using the straight-line method'

Variations from the suggested approaches:

'annual payments were assumed to be due at the beginning of the period as opposed to the end'

'the *investment expenditure* was incurred over more than one year, and were therefore reduced to a *present value* in the first year'

'it was assumed that the measure would take 6 months to implement'

Guideline 11: Additional issues relating to the implementation of cost data

We have identified a number of items in the data analysis stage for which we give guidance on best practice for recording methods and assumptions.

11.1. Defining scenarios

Scenarios constructed for national or international policy analysis often examine a package of measures applied to several sources in one or more sectors, with a mixture of existing measures in place, and a mixture of new plant measures and 'retrofit' to existing plant.

All assumptions used to construct a scenario should be recorded.

EXAMPLES

'Baseline emissions were forecast up to the year 2020 from the 1995 inventory assuming that emissions are related to population size. The populations shown in Table 1 are from the most recent year available. Populations and hence baseline emissions were forecast assuming compounded growth of 1% per year.'

'It was assumed that there is a replacement of technology A by technology B over a five year period from 2003 to 2008. It was further assumed that the replacement is linear, so that 20% is replaced each year.'

'The forecasts assume that the requirements of the legislation would be met as follows:

- all new plant would fit technology A;
- 5% of existing plant would retrofit technology A;
- 55% of existing plant would retrofit technology B and the complementary technology C;
- 30% of existing plant would retrofit technology D;

10% of existing plant would close, to be replaced by new plant.'

11.2. Sizes of emissions/releases/waste streams

It is recommended that emissions, releases and waste streams (E) are quoted as the product of an *emission factor* (F) and an *activity statistic* (A):

$$\boldsymbol{E = F \times A}$$

This approach aids the forecasting of future emissions from changes in the *activity statistic.*

For example, domestic waste arisings may be expressed as

$$\boldsymbol{E = \textit{arisings per capita} \times \textit{population}}$$

Whatever method is used, the origin of emission estimates should be stated.

EXAMPLES

'Emissions of 10 kt/yr were estimated assuming an *emission factor* of 1 g of pollutant per kg of product (this was the common view of the trade association's environmental committee), which was multiplied by a production of 10 Mt/yr (supplied by the Ministry of Industrial Production).'

'The average composition of leachate from the site was estimated by averaging the analyses of water taken from 25 boreholes across the site. The locations of the boreholes, sampling and analytical procedures have been described previously (Tanaka & Jansen, 1992).'

11.3. Forecasting emissions

Assumptions made in forecasting emissions should be stated. If the approach described in 11.2 above is followed, then forecasting uncontrolled emissions is simply a matter of forecasting the *activity statistic.* Controlled emissions may be forecast by modifying the *emission factor.*

EXAMPLE

'Emissions in the base year of 10 kt/yr were estimated assuming an *emission factor* of 1 g of pollutant per kg of product (this was the common view of the trade association's environmental committee), which was multiplied by a production of 10 Mt/yr (supplied by the Ministry of

Industrial Production). We assumed constant production over the forecast period, but a reduced *emission factor* of 0.8 g of pollutant per kg of product after 5 years (this assumes that some as yet unknown technical advance is achieved which eliminates the fugitive component).'

11.4. Interactions between environmental protection measures

The cost and effectiveness of a particular *environmental protection measure* applied to a particular process may be different if another measure has already been applied to that process. Alternatively the presence of measure 1 might preclude the use of measure 2. These interactions should be recorded.

The effectiveness of measures which are additive may vary according to the order in which they applied. Where additive measures are applied, their order of application should be stated.

EXAMPLES

'Incinerators may only be applied if the adhesive used is solvent-borne. If the adhesive is water-borne, then adsorption or biofiltration may be used.'

'If the sludge is first dewatered from 90% to 50% water content, for example by using a mechanical compressor, then the sludge transportation costs are reduced by 50 ECU per tonne.'

'The costs assume that technology A is applied before technology B. If the order is reversed the costs can be higher.'

11.5. Dealing with retrofit costs

The cost of retrofitting *environmental protection measures* to existing plant is generally higher than when similar measures are included in the design of new plant. This is due, for example, to issues such as space restrictions, special requirements on the design of the measure for the existing plant, and the costs of down time. If the existing plant is fairly old, then the *efficiency* of the measure might be reduced. The operating period over which the investment can be spread may also be reduced (this is only important if a study annualises the *investment expenditure*).

Background information to cost data should record whether *additional costs* and/or reduced *efficiencies* for retrofitted measures have been included.

Where these data are included, background information should be given to make comparisons easier. For example information could be given on:

- the type and size of process to which the measure is retrofitted;
- the age and expected lifetime of the existing process;
- any restrictions on the design, operation or *efficiency* of the measure such as space restrictions, noise limits, material availability, non-optimal operating conditions;
- additional maintenance costs;
- costs associated with installation and down time;
- the annualisation period (if relevant).

EXAMPLES

'Where the measure is retrofitted, installation would normally need to take place during the 2-week Christmas plant shut-down, so extra costs would need to be considered for overtime payments to contractors.'

'Gas collection systems can in principle be retrofitted to closed landfill sites. However allowance needs to be made for the cost of removing any existing cap material. If this is of unsuitable material it may need to be disposed of; in this case the availability of sufficient spare landfill volume usually determines the feasibility of the whole project.'

11.6. Aggregation

If cost data for individual measures are aggregated, for example within a scenario study, the aggregation method should be recorded.

EXAMPLES

'The transportation cost component was aggregated for the sector assuming that 10% of companies would incinerate wastes on site; 80% of companies would use a contractor for off-site incineration; and 10% of companies would be exempt and not use incineration.'

'It was assumed that members of the trade association represent 80% of production in the sector. The *operating and maintenance costs* reported by the trade association were therefore multiplied by 1.25 to derive the sector total.'

Glossary

Activity statistic

A measure of the size of a *pollution source*, for example its capacity, output, volume, or population. Activity statistics can be used, together with emission factors, to calculate emissions (see Guideline 11.2).

Additional cost/expenditure

This term refers to the difference between all costs incurred under the *base case* (i.e. in the absence of the *environmental protection measure*) and those costs incurred when the environmental protection measure is implemented.

Annual capital cost

An equal, or uniform, payment made over the useful life of the *environmental protection measure*, which has the same *present value* as the initial *investment expenditure*. The annual capital cost of an asset essentially reflects the *opportunity cost* to the investor of owning the asset.

Annual capital costs are equal to the initial *investment expenditure* multiplied by an appropriate *capital recovery factor*. Equally, annual capital costs may be approximated as the sum of an annual *depreciation charge* and the time-adjusted average interest charge on the unpaid balance.

Avoided costs

The value of any savings in labour, energy or materials inputs, relative to the *base case*, resulting from operating the *environmental protection measure*.

Base case

The term used to identify the situation prior to implementation of an *environmental protection measure*. In the context of scenarios or other future projections, the base case is the situation that would evolve in the absence of the policy/regulation under study; in this context the projection of the base case is often referred to as the 'business-as-usual' scenario, or 'baseline'.

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.

Capital recovery factor

A factor used to calculate the *annual capital costs* of an *environmental protection measure*. 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 measure.

Cash flow

For a given year, the cash flow associated with an *environmental protection measure* is the difference between ECU's received and ECU's paid out. Once the environmental protection measure is operational, for example, the cash flow in a given year will comprise *operating and maintenance costs* less income from the sale of by-products and any associated cost savings. Similarly, before the measure is operational the cash flow will only include *investment expenditures.* Cash flows thus only include costs as they are incurred.

Note: *depreciation charges* are not cash flows.

Constant prices

See *real prices.*

Current prices

See *nominal prices.*

Deflation

A decrease in the *general price level* or an increase in the *purchasing power* of money.

Depreciation charge

Capital goods (e.g. installed 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 of an asset to expense over the accounting periods making up its useful life.

Direct costs

Direct costs refer to those costs that can be primarily attributed to the *environmental protection measure.* That is, direct costs measure the value of the additional resources used to purchase, install, operate and maintain the environmental protection measure.

Discounted cash flow

The *present value* of expected future *cash flows.*

Discount factor

The *present value* of a single unit of currency (e.g. DM, £, ECU, $,...) received at some future date.

Discount rate

The rate used to discount future *cash flows* to their *present value.*

Discounting

The process of determining the *present value* of future *cash flows.*

Economic life

The time at which the marginal costs of operating and maintaining an *environmental protection measure* exceed the marginal benefits provided by the asset – 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 measure may differ from its *technical life*; the economic life is typically shorter than the technical life.

Efficiency

A measure of the effectiveness of an *environmental protection measure* in reducing emissions of a given pollutant from a given pollution source.

Emission factor

The estimated average emission rate of a given pollutant for a given source, relative to units of activity. For example, the estimated emission factor for carbon monoxide from U.S. gasoline -fuelled passenger cars with advanced three-way catalysts is 6.20 grams per kilometer. In this example the *activity statistic* is the number of kilometers driven by that type of car. Multiplying the emission factor by the activity statistic (for a city, State or total USA etc.) gives the total emissions for the specified region.

Environmental protection measure

In these Guidelines, an environmental protection measure means a measure which is aimed directly at the prevention, reduction or elimination of the emission of a given pollutant(s) arising from a given *pollution source*. Excluded from this definition are measures intended to improve safety in the workplace or improve industrial processes for economic reasons, even if this also results in genuine environmental improvements. Measures aimed at nature protection or natural resource management are also excluded.

Equivalent annual cost

An equal, or uniform, payment made over the useful life of an *environmental protection measure*, which has the same *present value* as the stream of annual cash outflows (i.e. the initial *investment expenditure* plus the series of net annual *operating and maintenance costs*) associated with the measure.

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. Increases in the price of specific goods and services does not necessarily imply that the average price level has changed. For example, increases in the price of gasoline may be offset by decreases in the price of electricity, in which case, the average price level will thus remain constant. For the average price level to move upward, the prices of a majority of commodities traded in an economy have to increase. Changes in the general price level are measured by the consumer *price index* with a *base year* assigned a value of 100.

Indirect costs

Indirect costs refer to those costs associated with changes in demand in related (markets) sectors of the economy through backward and forward production linkages with the *environmental protection measure*. For example, the (direct) expenditures on an environmental protection measure 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 investing in the environmental protection measure.

Inflation

An increase in the *general price level* or a decrease in the *purchasing power* of money.

Interest cost (charge)

A charge made for the use of money. 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 equipment or plant 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., if required.

Investment expenditure is distinct from the capital cost of an *environmental protection measure.* Capital goods provide services over a number of years and therefore only a portion of the original investment expenditure is recognised as an annual (capital) cost. In contrast, investment expenditure indicates the total value of the capital good in the year of acquisition and thus does not reflect the use of the asset over time.

Nominal (Current) prices

Nominal or current price variables refer to values at the prices ruling when the variable was measured. Such prices have not been adjusted for the effects of *inflation.*

Nominal discount/interest rate

Nominal or current price variables refer to values at the prices ruling when the variable was measured. Such prices have not been adjusted for the effects of *inflation.*

Operating and maintenance costs

The cost of the energy, labour, materials and environmental services required to operate and maintain the *environmental protection measure* during a single year. Operating and maintenance costs may 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 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 annually throughout the useful life of the environmental protection measure, 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.

Opportunity cost of capital

The expected rate of return that is foregone by investing in the *environmental protection measure* rather than in the best alternative investment.

Pollution source

A decision unit involving a set of one of more unit activities (processes), each generating one or more types of gaseous, liquid, solid and energy residuals. Examples include a refinery, a farm, a quarrying operation, a commercial building, a passenger car, a household, the management unit of a forestry, etc. Multiple sources of residuals may exist in a given pollution source, as well as multiple locations of residuals from a pollution source. A single petroleum refinery, for example, is a pollution source; individual unit processes within the refinery site are also pollution sources, as is the refinery sector as a whole.

Pollution sources can be categorised as (1) point, or concentrated sources; (2) dispersed sources; and (3) line sources, including mobile and stationary sources.

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.

Price deflator

A price indicator used to convert (to deflate) between *nominal* and *real* prices. The Gross Domestic Product (GDP) deflator at market prices is an example of such a price indicator. The GDP market prices deflator provides an index of inflation in the economy as a whole, and therefore is equally applicable in removing the effects of inflation from industrial and domestic prices.

Price index

Index numbers, which have no units, are values expressed as a percentage of a single base figure. For example, if the average current price of heavy fuel oil (HFO) was ECU 104.4 per tonne and ECU 115.3 per tonne in 1995 and 1996 respectively, the price in 1996 was 110 per cent of that in 1995. In index terms, the average price of HFO in 1995 and 1996 was 100 and 110 respectively. This is an example of a *current* price index. Price indices can just as easily be expressed in *real* terms by making the appropriate adjustments for *inflation.*

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 level of prices. They are inflation-adjusted prices.

Real discount/interest rate

A *nominal* discount/interest rate adjusted for *inflation* so that it represents an increase in purchasing power. The real discount/interest rate measures how much extra consumption you can have in period 2 if you give up some consumption in period 1.

Relative prices

The price of a particular good or service relative to other goods and services in general. If any good or service is expected to change relative to the *general price level*, then it is said to have changed in *real* terms.

Revenues

The annual income generated through, for example, the sale of materials recovered or energy generated from the operation of an *environmental protection measure*.

Side-effects

Effects arising from the implementation and operating of an *environmental protection measure* that are not included in the reported environmental performance and cost data. For example, an environmental protection measure designed to reduce road transport emissions may have 'side-effects' in terms of changes in accident rates and noise levels. Similarly, an environmental protection measure may reduce solid waste but increase air emissions.

Technical life

The estimated 'physical' life of an *environmental protection measures*, i.e. the time at which the asset literally wears out due to 'physical' deterioration. The estimated technical life of an *environmental protection measure* is a function of the assumed maintenance regime; a good repair policy may lengthen the life of the asset.

Time preference

Refers to the preference of an individual or society for current consumption versus future consumption. For example, if an additional unit of consumption in any one year has the same social value as 1.10 additional units of consumption in the following year, then the marginal time preference rate (or implied social discount rate) is 10 per cent.

Total annual cost

The total annual cost of an *environmental protection measure* corresponds to the uniform annual payment required to cover both the annual *operating and maintenance costs* net of *revenues/ avoided costs*, as well as the *annual capital costs* in the form of capital recovery and the cost of capital.

Appendix 1: A list of contributors

The Agency would like to express its gratitude to all those individuals and organisations who offered their comments and other valued assistance during the development of these Guidelines. Every attempt has been made to include contributors in the following list, but the list may not be exhaustive.

Markus Amann, International Institute for Applied Systems Analysis (IIASA) (International)
Mark Ambler, Coopers and Lybrand, UK
Katy Anderson, Aspinwall & Company, UK
Kevin Andrews, Water Research Centre, UK
Helen ApSimon, Imperial College, UK
Simon Aumonier, Ecobalance, UK
Filomena Boavida, Ministry of Environment, Portugal
Stanislav Bogdanov – National Institute of Meteorology and Hydrology, Bulgaria
Heinz Bollmacher, VDI, Germany
Rémy Bouscaren, Centre Interprofessionel Technique d'Etudes de la Pollution Atmosphérique (CITEPA), France
Richard Boyd, Metroeconomica, UK
Herald Bradke, Fraunhofer Institute for Systems and Innovation Research, Germany
Charlotte Breuvard, European Commission DGIII (International)
Christian Bruijnes, Ministry of Housing, Spatial Planning and the Environment, Netherlands
Mario Camani, Sezione Protezione Aria e Acqua, Switzerland
Peter Carter, European Investment Bank (International)
Antonio Ferreiro Chao, AED SA, Spain
Alessandro Colombo, Joint Research Centre Ispra (International)
Arnaud Comolet, Planistat Europe, France
Clare Cottingham, Department of the Environment, Transport and the Regions, UK
Pierre Couteau, Rhône-Poulenc, France
David Cowell, Imperial College, UK
Bart de Boer, Centraal Bureau voor de Statistiek, Netherlands
David de Jager, Ecofys, Netherlands
Marc Deslauriers, Environment Canada
Dominique Dron, Ministry of Environment, France
Hans Eerens, RIVM, Netherlands
Jonathan Fisher, private consultant, UK
Wayne Fraser, Hudson Bay Mining and Smelting Co. Ltd., Canada
R. Fuchs, BASF, Germany
Janina Fudala, Institute for Ecology of Industrial Areas, Poland
Walter Ganapini, Agenzia Nazionale per la Protezione dell'Ambiente, Italy
Françoise Garcia, ADEME, France
Ulrich Geffarth, Cefic (International)
Dolf Gielen, Netherlands Energy Research Foundation (ECN), Netherlands
Pierre Girboux, Electrabel, Belgium
Ed Glennie, Water Research Centre, UK
Hugh Goldsmith, European Investment Bank (International)
Teresa Gonzales, Imperial College, UK
Lea Gynther, Ekono Energy Ltd, Finland
Svein Haagenrud, Building Research Institute, Norway
Aldert Hanemaaijer, RIVM, Netherlands
Toon van Harmelen, TNO, Netherlands
Keith Harsham, Cefic (International)
Walter Hecq, CEESE-ULB, Belgium
Heddeke Heijnes, Institute for Applied Economics (TME), Netherlands
Chris Hendriks, Joint Research Centre IPTS (International)
Jan Henriksen, Norwegian Institute of Air Research (NILU), Norway
Tony Holloway, Chem Systems, UK
Thomas Holtmann, French-German Institute for Environmental Research (IFARE), University of Karlsruhe, Germany
Alexandra Howarth, Economics for the Environment Consultancy Ltd (EFTEC), UK
Jochem Jantzen, Institute for Applied Economics (TME), Netherlands

Carrie Johnson, AEA Technology, UK
Ola Jonsson, Swedish Environmental Protection Agency, Sweden
Wolfram Jörß, Umweltbundesamt, Germany
George Kallos, University of Athens, Greece
Ute Karl, French-German Institute for Environmental Research (IFARE), University of Karlsruhe, Germany
Katie King, AEA Technology, UK
Zbigniew Klimont, International Institute for Applied Systems Analysis (IIASA) (International)
Walter Kuit, Cominco Ltd., Canada
José Laffond, Environment Transport and Planning, Spain
Mark Lea, Department of Trade and Industry, UK
Christine Lecuyer, EDF, France
Andreas Lorenz, Umweltbundesamt, Germany
Mercedes Garcia Luna, TAU Consultora Ambiental, Spain
Ian Marlowe, AEA Technology, UK
Ruud Meij, KEMA Nederland BV, Netherlands
Paul Miller, Department of the Environment, Transport and the Regions, UK
Maciej Nowicki, EcoFund, Poland
Xander Olsthoorn, Free University of Amsterdam, Netherlands
Hans Oonk, TNO, Netherlands
Rudolf Orthofer, Austrian Research Centre, Austria
Ece Ozdemiroglu, Economics for the Environment Consultancy Ltd (EFTEC), UK
Elisabeth Pacyna, Norwegian Institute of Air Research (NILU), Norway
Jozef Pacyna, Norwegian Institute of Air Research (NILU), Norway
Mr. Peirani, Ministry of the Economy, Finance and Industry, France
Peter Pichl, Umweltbundesamt, Germany
Nicola Pirrone, University of Calabria, Italy
Walter Pfluegner - PlanEVAL, Germany
Vicky Pollard, Environment Agency, UK
Walter Radermacher, Statistisches Bundesamt, Germany
Stefan Reis, University of Stuttgart, Germany
Otto Rentz, French-German Institute for Environmental Research (IFARE), University of Karlsruhe, Germany
Wolfgang Riege-Wcislo, Statistisches Bundesamt, Germany
Pierce Riemer, IEA Greenhouse Gas R&D Programme (International)
Alistair Ritchie, Entec, UK
Bernd Schärer, Umweltbundesamt, Germany
Werner Schulz, Umweltbundesamt, Germany
Eberhard Seifert, Wuppertal Institute, Germany
Irene Smith, IEA Coal Research (International)
Herminé Soud, IEA Coal Research (International)
Anton Steurer, EUROSTAT (International)
Ralph Thurm, Siemens, Germany
Kerry Turner, Centre for Social and Economic Research on the Global Environment (CSERGE), UK
Eloy Unzalu, LABEIN, Spain
Rita Vaccaro, Techne, Italy
Michalis Vassilopoulos, Joint Research Centre IPTS (International)
Kees van Leeuwen, Concawe (International)
Peter Vercaemst, VITO, Belgium
Thomas Verheye, European Commission DGXI (International)
Rachel Warren, Imperial College, UK
William Watts, European Commission DGII (International)
Mike Wenborn, AEA Technology, UK
Gia Wickbom, Statistics Sweden
Michal Wilczynski, EcoFund, Poland
Rupert Willis, European Commission DGXI (International)
Maria Elisabeth Wolf, Central Statistical Office (Östat), Austria
Mike Wright, Cefic (International)
Karl-Heinz Zierock, Umweltbundesamt, Germany
Tomasz Zylicz, Warsaw University, Poland

Appendix 2: Overview of previous guidelines

Numerous documents exist offering varying degrees of advice to analysts conducting environmental costing studies. In the scoping study of this project we identified 16 such documents (see references section). However, not all of these were reviewed in detail. Effort was focused on those documents that:

- were used most frequently by interviewees;
- could be referred to as 'guidelines', as opposed to environmental costing studies, which contained a brief overview of the methodology followed;
- focused on estimating the cost of environmental protection measures[3].

Furthermore, Scharer (1995), Rentz *et al.* (1987) and UN ECE (1988) present a very similar methodology. Therefore, while we only make reference to UN ECE (1988) in the discussion below, it can be assumed that the other two guidelines offer similar advice. Significant similarities also exist between VROM (1994), CBS (1996) and Hueting *et al.* (1992). Consequently, we will only make reference to the former.

The following discussion is divided into five sub-sections:

- Cost data;
- Handling of cost data;
- Source sectors to which environmental protection measures are applied;
- Environmental protection measures;
- Pollutants.

For each of the sub-sections a summary table is given showing the coverage of existing guidelines and more detailed discussion follows each table.

Cost data

Table 1 summarises existing guidelines which deal with cost data; each issue is then discussed in more detail below.

[3] This eliminates Department of the Environment (1996) and Institution of Chemical Engineers (1988). The former is concerned with estimating the cost of complying with all forms of government regulations. Furthermore, it offers advice more on when and by whom things should be done as opposed to how they should be done. The latter is concerned with estimating the capital cost of industrial plant and facilities, and it not really applicable to environmental costing.

Table 1: Summary of the coverage of existing guidelines regarding cost data

Issue	Existing Guidelines
1.1 Limited cost data are available and not enough background information and/or assumptions are provided with the available data.	In general, none of the existing guidelines address this issue satisfactorily.
1.2 Details of cost components.	Most of the main guidelines both identify and define the cost components to be included in an environmental costing study. However, there are inconsistencies in the definitions used across the guidelines.
1.3 Apportioning costs to more than one pollutant or impact.	This issue is recognised by some of the guidelines, but not much advice is given on how to deal with it.
1.4 Additional cost of environmental protection measures retrofitted to existing processes.	Retrofitting is identified as a special case by only one of the guidelines, but not much advise is given on how it should be dealt with.
1.5 Variations in cost data with location.	This issue is not addressed by any of the existing guidelines.
1.6 Uncertainties with normalisation and cost-effectiveness terminology.	To be covered in future work.

Limited cost data are available and not enough background information and/or assumptions are provided with the available data
Few of the existing guidelines identify possible sources of cost data; the exceptions are Department of the Environment (1996) and IPCC (1996). However, the data sources listed in the former are UK-specific, relate to non-environmental as well as environmental regulations, and are therefore not particularly useful for environmental cost assessment at a European scale. The data sources listed in IPCC (1996) relate solely to the mitigation of greenhouse gas emissions, and thus have restricted use.

None of the guidelines examined explicitly states that analysts should list all the assumptions they have made, or what information should be obtained along with the raw data.

Details of cost components
VROM (1994), HMIP (1990) and UN ECE (1988) all outline what components should be included in the annual cost calculations, e.g. capital, operating and 'recovery credit' components, and offer a detailed definition of each. However, not all the guidelines go into this amount of detail, and individual components are not always defined consistently, e.g. HMIP (1990), FSO (1996) and VROM (1994) define capital costs differently. Furthermore, not all guidelines list every potential cost component, e.g. VROM (1994) is the only guideline that makes reference to transfer payments.

Apportioning costs to more than one pollutant or impact
Partitioning the cost of an investment, which has both environmental and non-environmental consequences, for example between the two sets of consequences, is recognised as a problem by UN ECE (1988) and VROM (1994), but not much guidance is given on the 'mechanics' of how to deal with it. In the case of process-integrated control measures, both guidelines only suggest determining the difference in costs between an integrated plant and a comparable reference production unit without pollution control; the difference should be allocated to the pollution control measure.

VROM (1994) addresses the potential problem of what is and what is not included in the cost data through the application of strict definitions. For example, based on their definition of environmental costs, measures which also protect occupational health and safety are not included in the cost data. In addition, VROM (1994) considers a series of borderline cases and suggests whether or not an investment should be considered environmental or not. However, the guideline does not say how to perform the allocation; rather it only suggests when it might be necessary.

None of the guidelines offers any advice on how to allocate the annual costs of an entire pollution control system to a single pollutant, which is the focus of a study, when the system actually abates several pollutants. On a somewhat related issue, FSO (1996) briefly discusses the need to take the interaction of pollution abatement techniques into account. Interactions arise, for example, when the introduction of technique A can reduce the scope for pollution reduction technique B.

Additional cost of environmental protection measures retrofitted to existing processes
Only UN ECE (1988) identifies retrofitting as a 'distinct case', necessitating a special approach to determining the investment and operating costs. The only guidance given, however, suggests that the additional annual cost arising from incorporating equipment into existing production processes should be calculated and reported separately. The guideline also gives a couple of examples of when additional costs are likely to arise.

Variations in cost data with location
None of the guidelines examined in this study offers any advice on how to deal with price variations across regions/countries.

Uncertainties with normalisation and cost-effectiveness terminology
These issues should be covered in future work on guideline development.

Handling of cost data

Table 2 summarises existing guidelines relating to data handling for cost data.

Table 2: Summary of the coverage of existing guidelines regarding handling of cost data

Issue	Existing Guidelines
2.1 Base year for cost data.	None of the existing guidelines explicitly requires that the base year of the cost data be stated.
2.2 Base year for technology	None of the existing guidelines explicitly requires that the base year of the technology data be stated.
2.2 Changes in cost of environmental protection measures with time.	Although this issue is recognised, none of the existing guidelines give satisfactory advice on dealing with it.
2.3 Baseline scenario	To be covered in future work.
2.4 Uncertainties related to annualised costs.	All the guidelines require costs to be annualised. However, some of the guidelines do not suggest how to do this, and there are methodological inconsistencies between those that do.
2.5 Discount and interest rates.	The issue of discount rates and interest rates is discussed to varying degrees of detail in the existing guidelines.
2.6 Uncertainties in methodologies not adequately quantified.	The existence of significant uncertainties is recognised, but little guidance is given on how to deal with them.

Base year for cost data
Specification of the base year is not required by any of the existing guidelines. However, both VROM (1994) and HMIP (1990) indirectly require that the base year of the cost data is specified, by recommending that all costs are valued using real prices instead of nominal prices; use of the former necessitates the specification of a base year as all reported prices are normalised to that year. On a related subject, none of the guidelines requires that the base year of the technology should be specified.

Changes in cost of environmental protection measures with time
The need to inflate prices to allow for price developments over time is recognised by VROM (1994). To accomplish this the guideline recommends using several price indices published by the Central Bureau of Statistics. These price indices are specific to the Netherlands, and are thus not generally applicable throughout Europe. HMIP (1990) also recognises that sometimes it is necessary to forecast prices over time. The guideline does not, however, suggest how this should be done, although HMIP (1990) does realise the importance of using real price forecast as opposed to nominal price forecasts. The use of real prices facilitates the identification of prices that move differently from those in the rest of the economy, i.e. as a result of general price inflation. Hence, any movements in real prices over time are a result of changes in supply and demand conditions.

It is worth noting that neither guideline gives a satisfactory explanation as to why real prices differ from nominal prices, or any guidance on how to convert nominal prices to real prices and vice versa.

Baseline scenario

Issues related to baseline scenarios should be covered in future work on guideline development.

Uncertainties related to annualised costs
There are several methods recommended in the guidelines for calculating annualised costs. VROM (1994), UN ECE (1988), and Rentz (1987), for example, define annual costs as:

Annual costs	=	capital cost (annual depreciation plus interest)	+	annual operating costs	-	annual savings /receipts

FSO (1996) suggest a variation of this method. HMIP (1990) define annualised costs slightly differently: capital costs (capital expenditure divided by an appropriate annuity factor) + as above. Other guidelines make reference to annualised costs without suggesting how they should be calculated. Although not mentioned in any of the guidelines, other methods exist for determining the annual cost of an investment. Furthermore, none of the guidelines discuss the 'strengths' and 'weaknesses' of the approach they suggest, or how it relates to other methods.

Discount and interest rates
Coverage of discount rates and interest rates varies between the guidelines. For example, UN ECE (1988) says nothing more than 'interest rates can be related to long-term capital market rates.'; whereas, IPCC (1996) devotes an entire chapter to the theoretical and empirical issues associated with intergenerational equity and social discounting. The treatment of discount rates and interest rates in each guideline depends on the method each recommends for calculating annual costs. HMIP (1990), which recommends a discounted cash flow annualisation method, suggests using a real discount rate as given by the pre-tax cost of capital to the operator. On the other hand, VROM (1994), which recommends a non-discounted cash flow annualisation method, discusses interest rates as opposed to discount rates. The discussion in VROM (1994) is thorough. However, the empirical estimates are only applicable to the Netherlands. The importance of maintaining consistency between the use of real prices and real discount rates is only mentioned in a couple of the guidelines. It is worth noting, that only IPCC discusses the rationale behind discounting.

Uncertainties in methodologies not adequately quantified.
The majority of the guidelines do not satisfactorily address the issue of uncertainty. Only IPCC (1996) actually defines uncertainty. However, the accompanying discussion on how to incorporate uncertainty into quantitative models for decision making is more relevant to using the cost data than to collecting it. HMIP (1990) is one of the only guidelines to recognise the existence of uncertainty. It explains how sensitivity analysis can be used to identify potential sources of uncertainty, but does not go on to suggest how these uncertainties can be minimised or conveyed to users of the cost data. In fact, a lack of recommended methods for quantifying/reporting uncertainties is a problem common to all the guidelines.

Source sectors to which environmental protection measures are applied

Table 3 summarises existing guidelines relating to source sectors.

Table 3: Summary of the coverage of existing guidelines regarding source sectors

Issue	Existing Guidelines
3.1 Details of pollution source.	This issue is not addressed satisfactorily by the available guidelines.
3.2 Source sector classifications.	This issue is not addressed satisfactorily by the available guidelines.

Details of pollution source
Source sectors are not discussed in any detail in the available guidelines. In fact, only FSO (1996) makes any reference to the 'sources' of pollution. This guideline defines a source sector within a hierarchical framework, with emissions linked to sources, sources linked to techniques, techniques to source sectors, and finally source sectors to economic production processes. Whilst each element of this framework is defined in general terms, no guidance is given with respect to the amount of 'technical' data required.

Source sector classifications
FSO (1996) is also the only guideline that makes any reference to a source sector classification system. It uses the EU standard statistical nomenclature for economic activities, i.e. NACE, to define economic production processes. However, alternative systems are not mentioned. Furthermore, FSO (1996) recognises that it is not always possible to link economic production processes, as defined by NACE, to technical source sectors. It fails to give satisfactory guidance on how to deal with this, however.

Environmental protection measures

Table 4 summarises existing guidelines relating to environmental protection measures.

Table 4: Summary of the coverage of existing guidelines regarding environmental protection measures

Issue	Existing Guidelines
4.1 Applicability of environmental protection measures.	This issue is not satisfactorily addresses in the existing guidelines, although one of the guidelines discusses the incompatibility of some environmental protection measures.
4.2 Lack of information on the performance characteristics of environmental protection measures.	This issue is not addressed by any of the existing guidelines.
4.3 Environmental protection measures included in cost studies.	The main groups of environmental protection measures are adequately defined in some of the guidelines, but the focus is on technical measures and not many examples are given.
4.4 Existing environmental protection measures.	Only one of the guidelines recognises the need to identify measures already in-situ.
4.5 Future/developing technologies.	This issue is not satisfactorily addressed by any of the available guidelines.
4.6 Lifetime of environmental protection	Most of the guidelines implicitly require that

measures.	the lifetime of each environmental protection measure be specified.

Applicability of environmental protection measures
The applicability of environmental protection measures to source sectors is not discussed in any of the available guidelines. A partially related issue, however, is addressed in FSO (1996). This relates to the incompatibility of pollution abatement techniques with one another. FSO (1996) distinguishes between two types of incompatibility: strict technical incompatibility and incompatibility related to sunk costs. These are defined in detail, including examples. Ways to deal with both types of incompatibility are also suggested.

Lack of information on the performance characteristics of environmental protection measures
None of the existing guidelines examined make any reference to the type and amount of performance data that should be collected for each environmental protection measure. No guidance is also given on how the efficiency of each measure will vary with time, or subject to different operating conditions.

Environmental protection measures included in cost studies
The majority of the guidelines adequately define what constitutes an environmental protection measure. For example, UN ECE (1998) basically defines all 'techniques' which reduce impact on the environment as environmental protection measures. Furthermore, all such measures should be considered in a cost study. Similarly, VROM (1994) says that any expenditure on a measure for the explicit purpose of preventing or abating the undesirable effects of human activities or operations on the environment should be included in an environmental costing study. VROM (1994) and FSO (1996) also distinguish between :

1. technical measures, including end-of-pipe measures and process-integrated measures;
2. product-based measures;
3. volume reduction measures;
4. procedural measures.

None of the guidelines, however, give examples of each type of measure, or discuss how each should be treated; for example, how should an end-of-pipe measure be assessed in contrast to a procedural measure.

Existing environmental protection measures
Only FSO (1996) explicitly recognises that a measure's emission reduction potential and corresponding cost depends strongly on the techniques already in use, and therefore discusses the need to define a reference or baseline situation. The guideline requires the specification of a base year, including a detailed and quantitative description of the technical measures in use in that year and the corresponding emission reduction potential. To perform this task, the guideline identifies the types of information required for each source sector.

Future/developing technologies
The inclusion of 'future or developing technologies' is not strictly mentioned in any of the guidelines. FSO (1996) realises that it may be necessary to define a future baseline scenario; i.e. it may it may be necessary to generate hypothetical scenarios for certain years in the future.

Lifetime of environmental protection measures
Regardless of which annualisation method is recommended by a guideline, it is not possible to calculate the annual cost of an environmental protection measure without knowing its operating life. Therefore, it can be said that the majority of the guidelines require the operating life of the environmental protection measure to be stated. This includes UN ECE (1988), HMIP (1990), Rentz (1987), FSO (1996) and VROM (1994).

Pollutants

Table 5 summarises existing guidelines relating to pollutants.

Table 5: Summary of the coverage of existing guidelines regarding pollutants

Issue	Existing Guidelines
5.1 Uncertainty in emission estimates.	In general, this issue is not covered adequately by the existing guidelines; although it is beyond the scope of some guidelines.
5.2 Definitions of pollutants.	This issue is not addressed by any of the existing guidelines.

Uncertainty in emission estimates
Many of the guidelines, e.g. VROM (1994) and UN ECE (1988), do not discuss cost-effectiveness analyses whose evaluation requires emission data. Hence, no guidance is given on collecting emission estimates. Of the guidelines which are concerned with cost-effectiveness analysis, only HMIP (1990) makes reference to the information that should be provided to enable the environmental emissions to be quantified, e.g. concentration, release rate and total annual burden. The guideline also recommends that this information be provided for different operating conditions.

Definitions of pollutants
None of the existing guidelines examined in this study discusses problems associated with classifying pollutants.

Overview of Existing Guidelines - Key Points
16 existing guidelines have been identified and reviewed, but many guidelines contain similar information.

From the interviews with cost experts and cost data users, the UN ECE (1988) and VROM (1994) guidelines are the most useful.

Concerning the 5 key problems / issues (as voted at the scoping study workshop), the existing guidelines cover the following :

Details of cost components.

- most of the main guidelines both identify and define the cost components, but there are inconsistencies in the definitions used across the guidelines.

Apportioning costs to more than one pollutant or impact.

- this issue is recognised by some of the guidelines, but limited advice is given on how to deal with it.

Discount and interest rates.

- the issue of discount rates and interest rates is discussed to varying degrees of detail in the existing guidelines.

Uncertainties in methodologies not adequately quantified.

- the existence of significant uncertainties is recognised, but limited guidance is given on how to deal with them.

Lifetime of environmental protection measures.

- most of the guidelines implicitly require that the lifetime of each environmental protection measure be specified.

Appendix 3: Definitions of pollutants

Inconsistencies in the definitions of pollutants are common. Examples of problems with classifications of pollutants includes:

- types of waste: e.g. household waste - does this include garden waste, sewage, or just waste collected by local authorities etc.? or e.g. sewage sludge - does this include sewage sludge from both municipal and on-site industrial waste water treatment works?
- toxic organic pollutants: does this include pesticides, and if so which ones; and which other pollutants are included?
- VOCs: quantities of VOCs are expressed as carbon, methane equivalent, hexane equivalent, propane equivalent etc.

It is recommended to use and reference definitions from internationally recognised systems (e.g. waste catalogues, OECD and UNECE classifications, etc.) and from international regulations.

References to pollutant definitions

Waste:

Defined in Directive 91/156/EEC on Weste (framework) (OJ L78 26 March 1991).

Hazardous waste:

Defined in Directive 94/31/EEC on Hazardous Waste (OJ L168 2 July 1994).

Inert wastes:

Defined in draft Directive on the landfill of wastes (COM(97) 105 March 1997).

Chemical pollutants:

Single substances, and some mixtures of substances, are defined by Chemical Abstracts Service Registry Numbers (CAS Numbers).

76/464/EEC Directive on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community (OJ L129 18 May 1976) 86/280/EEC Directive on limit values and quality objectives for discharges of certain dangerous substances included in List I of the Annex to Directive 76/464/EEC (OJ L181 4 July 1986), amended by 88/347/EEC (OJ L158 25 June 1988), 90/415/EEC (OJ 14 August 1990).

Volatile organic compounds:

Defined in UN Protocol to the 1979 Convention on long-range transboundary air pollution concerning the control of emissions of volatile organic compounds or their transboundary fluxes (1991). ECE/EB.AIR/30.

Persistent organic pollutants:

Defined in the Protocol to the Convention on Long-Range Transboundary Air Pollution on Persistent Organic Pollutants. (Press Release ECE/ENV/98/4 February 1998 web site http://www.unece.org/env/env_eb.htm)

Heavy Metals

Defined in the Protocol to the Convention on Long-Range Transboundary Air Pollution on Heavy Metals. (Press Release ECE/ENV/98/4 February 1998 web site http://www.unece.org/env/env_eb.htm)

PCBs:

Defined in Directive 76/403/EEC.

Particulates:

PM_{10} is defined in ISO 7708:1995(E) 'Air Quality - Particle size fraction definitions for health-related sampling'.

NO_x:

Defined in the 1988 Sofia Protocol concerning the Control of Emissions of Nitrogen Oxides or their Transboundary Fluxes (http://www.unece.org/env/env_eb.htm).

Water quality parameters:

75/440/EEC Directive concerning the quality required of surface water intended for the abstraction of drinking water in Member States (OJ L194 25 July 1975), amended by 79/869/EEC (OJ L271 29 October 1979)

76/160/EEC Directive concerning the quality of bathing water (OJ L31 5 February 1976).

Appendix 4: Further guidance on documenting cost components

Studies and databases should explicitly state which of the cost components and benefits listed below have been included in the reported cost data.

The following hierarchy for reporting costs data is recommended.

1. As a minimum, the total *investment expenditure* and total annual *operating/maintenance costs* should be reported separately.

2. Where possible, *investment expenditure* should be split between pollution control equipment expenditure and installation expenditure.

3. Annual *operating and maintenance costs* should be split between energy, materials and services, labour, and fixed *operating/maintenance costs.*

4. If it is possible to disaggregate the cost data further between the individual cost elements, then this should be done.

Check-list of cost components

1. Investment Expenditure

1.1 Pollution Control Equipment Expenditure

This element of *investment expenditure* may include, for example, *additional expenditure* relating to the purchase of:
- primary pollution control devices
- auxiliary equipment
- instrumentation
- any associated freight of equipment
- modifications to other equipment

[Note: The type(s) of equipment purchased should be given.]

1.2 Installation Expenditure

This element of *investment expenditure* may include, for example, *additional expenditure* relating to:
- project definition, design, and planning
- the purchase of land
- contaminated land clean-up costs (if required at purchase)
- 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
- contaminated land clean-up costs (at end-of-life of plant)

(Note: Where known, the time taken to install the abatement equipment should be given.)

2. Annual *Operating and Maintenance Costs*

2.1 Energy Costs

This element of *operating and maintenance costs* may include, for example, *additional costs* relating to the purchase of:

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

(Note: Where known, the grade of fuel should be given.)

2.2 Materials and Services Costs

This element of *operating and maintenance costs* may include, for example, *additional costs* relating to:

- replacement parts
- chemicals
- environmental services such as waste treatment and disposal services

2.3 Labour Costs

This element of *operating and maintenance costs* may include, for example, *additional costs* relating to:

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

2.4 Fixed Operating/Maintenance Costs

This element of *operating and maintenance costs* may include, for example, *additional costs* relating to:

- insurance premiums
- license fees
- emergency provisions
- other general overheads

Examples of benefits, revenues and avoided costs

Benefits

- improved product quality
- increased market share
- reduced safety management requirements

Revenues

- sale of treated effluent for irrigation
- generated electricity sales
- sale of ash for building materials

Avoided costs

- energy use
- materials and services
- labour

Appendix 5: Attributing costs to environmental protection

This Appendix summarises guidance given in VROM (1998) on how to decide when a cost may be attributed to environmental protection as opposed to other purposes. This Appendix was not reviewed during the consultation process described in the Introduction to the *Guidelines for defining and documenting data on costs of possible environmental protection measures.*

Environmental costs are calculated on the basis of extra costs incurred for environmental purposes. Four types of *environmental protection measure* are considered in the guidance:

- technical measures;
- product-based measures;
- volume-reduction measures;
- procedural measures.

Technical measures
An end-of-pipe measure will normally have no purpose other than to reduce environmental damage so the entire *investment expenditure* and *operating and maintenance costs* can be regarded as environmental costs.

Difficulties arise with process-integrated measures. These can affect the entire production process, and often serve other purposes. VROM suggests to compare the costs 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. If a clear comparison cannot be made then judgements must be made on a case-by-case basis.

If savings arise which are greater than the environmental component then the environmental costs will be taken into account if the payback time of the measure is longer than 3 years (5 years for civil projects). If the payback time is less than 3 years it is assumed to be economically viable and thus not primarily driven by environmental considerations and therefore not considered as an environmental protection measure.

In theory, after a period of time, a given technical measure which is beneficial for the environment might become standard and less environmentally benign alternatives might cease to be available. When such a situation occurs, the measure is regarded as no longer incurring environmental costs.

Product-based measures
Environmental costs may arise when a product is modified - for example using a more costly input material or an extra addition to the end product. Attribution to environmental protection is similar to the case for technical measures.

Volume-reduction measures
Volume-reduction measures aim to regulate the number of emitting units as opposed to the emissions per unit. When such measures lead to a loss in the value of assets then the costs of this will count as environmental costs. All other costs (e.g. loss of production, earnings or employment) are considered as economic effects to be considered in modelling but not as cost components as intended in the present *Guidelines for defining and documenting data on costs of possible environmental protection measures.*

Procedural measures
Procedural measures include research, co-ordination, management systems and administration. Attribution of environmental costs is similar to the case for technical measures.

Appendix 6: References

CBS and C3ED (1996) ***Methodological Problems in the Calculation of Environmentally Adjusted National Income Figures,*** Study for the EC DGXII.

Commission of the European Communities (1992) ***Proposal for a Council Directive on the incineration of hazardous waste***

Department of the Environment (UK) (1996) ***Checking the Cost to Business; A Guide to Compliance Cost Assessment***, HMSO London.

Department of Trade and Industry (DTI) ***Energy projections in the UK (Energy Paper 65).*** March 1995. HMSO London.

FSO (1996) Federal Statistical Office, Germany and Statistics Netherlands. ***The construction of abatement costs curves: methodological steps and empirical experiences***, to be published in the International Journal of Sustainable Development, Volume 1 Number 2, Special Issue on Green National Accounting, Guyancourt 1999.

HMIP (1990) Environmental Protection Act 1990 ***Technical Guidance Note E1 (Environment): Environmental, Economic and BPEO Assessment for Integrated Pollution Control***, Three Volumes, (Draft).

Hueting, R., Bosch, P. and de Boer, B. (1992) ***Methodology for the calculation of sustainable nation income,*** Report M44, Centraal Bureau voor de Statistiek.

Institution of Chemical Engineers and The Association of Cost Engineers (1988) ***A Guide to Capital Cost Estimating***, 3rd Edition.

IPCC (1996) *Climate Change 1995: Economic and Social Dimensions of Climate Change* Cambridge University Press.

VROM (1994) Netherlands Ministry of Housing, Spatial Planning and the Environment. ***Method for Environmental Costing - Background document***, Report number 1994/1 Environmental Management Publications Series.

VROM (1995) Netherlands Ministry of Housing, Spatial Planning and the Environment. *Kosteneffectiviteit van milieumaatregelen in de industrie (Beschrijving van de methodiek*, deel A).

VROM (1998) *Kosten en baten in het milieubeleid - Definities en berekeningsmethoden*, VROM 97572/h/10-98 14540/176.

Rentz, O., Remmers, J. and Plinke, E. (eds) (1987) *Proceedings from a Workshop on Emission Control Costs - Methodology and Example Cases*, Esslingen am Neckar, Germany.

Scharer B (1995) ***Methodology for determining the cost of environmental protection measures.***

UN ECE (1988) ***Draft Guidelines for determination of the cost of emission control activities*** (Working Party on Air Pollution Problems, 17th session, Geneva 15-17 June 1988)

VDI Konnission Reinhaltung der Luft (1979) ***Kostenermittlung für Anlagen und Maßnahmen zur Emissionsminderung*** (VDI 3800).