# IPPC Permitting

## A Practical Guide

*June 2005*

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**IPPC[1] Permitting**

**A practical Guide**

# 1. Key messages[2]

- **BREFs do not define emission limit values, but emission ranges corresponding to BAT.**
- **BREFs are not intended to impose specific techniques; they have the sole purpose of deriving BAT and BAT-associated emission ranges and of indicating how these ranges can be achieved.**
- **Not all techniques mentioned as BAT in a BREF can be applied simultaneously to a single installation. Some are incompatible, some are redundant, some may not apply to the specific process in question**
- **It is the responsibility of the Operator to justify his/her technical options compared to the BAT**
- **ELVs defined on the basis of BAT-associated emission ranges must take the variability of emissions into account, including variability over time for a given plant and plant to plant variability.**
- **ELVs do not represent actual emissions but just maximum allowed emissions**
- **Environmental Quality Standards relate to the receiving body, not to an effluent stream.**
- **Cost effectiveness of every emission reduction measure should be evaluated on its own merits i.e. on the resulting incremental improvement against the incremental cost versus the next best alternative.**
- **When requiring excessive costs, very low emission rates are not in line with the definition of BAT in IPPC, which are meant to achieve a high level of environmental protection, not the highest (Art 1).**
- **For existing installations, short notice of implementation of tight limits can necessitate selecting suboptimal technical solutions. Pace of implementation must therefore be part of the discussion with Authority.**
- **The same general rules apply for new and existing installations regarding ELVs determination. However cost and length of time for implementation could be very different.**
- **All existing and new IPPC installations must have an IPPC permit by October 2007 at the latest.**

[1] Integrated Pollution Prevention and Control – Council Directive 96/61/EC
[2] BAT = Best Available Techniques; BREF = Best Available Techniques Reference Document; ELV = Emissions Limit Values

## 2. Scope

This note has been developed to help Cefic member companies and associations to support discussion on permit conditions, especially ELVs, for a given installation in a local context, based on BAT as expressed in the BREFs, and to address the questions an operator may face when writing his application for a permit (or when updating an existing permit), for instance:

- The sectoral BAT as described in the BREF may differ from the techniques used by the operator, or implementation of the same technique may lead locally to different performances. What to do?
- Emissions from a plant applying BAT result in an environmental impact that is compared to an Environment Quality Standard. What if the impact is higher than allowed by the EQS?
- The Authority wants to apply a regional/national emission reduction programme. How can a cost effectiveness methodology help the operator to discuss this?

This Guide covers the various issues related to IPPC permits:

a. Fundamental concepts: BAT-associated emission ranges, Emission Limit Values, sectoral BAT and site-specific BAT.
b. Environmental Quality Standards
c. Quantification of local impact
d. Cost effectiveness
e. Emissions Reduction Programme

The fundamentals concerning IPPC can be found in the document in reference 1 (IPPC - Cefic Guidance Document), particularly pages 6-10 on BREF content and nature.
On the other hand, it may be useful to recall some extracts from the Standard Preface, common to all BREFs:

"The information provided in this document *(the BREF)* is intended to be used as an input to the determination of BAT in specific cases. When determining BAT and setting BAT-based permit conditions, account should always be taken of the overall goal to achieve a high level of protection for the environment as a whole.
...
Chapter 5 *(of the BREF- usually chap.5 corresponds to the chapter containing the BAT conclusions; however, according to the sector, the structure and chap. N° may vary)* presents the techniques and the emission and consumption levels that are considered to be compatible with BAT in a general sense. The purpose is thus to provide general indications regarding the emission and consumption levels that can be considered as an appropriate reference point to assist in the determination of BAT-based permit conditions or for the establishment of general binding rules under Article 9(8). It should be stressed, however, that this document *(the BREF)* does not propose emission limit

values. The determination of appropriate permit conditions will involve taking account of local, site-specific factors such as the technical characteristics of the installation concerned, its geographical location and the local environmental conditions. In the case of existing installations, the economic and technical viability of upgrading them also needs to be taken into account. Even the single objective of ensuring a high level of protection for the environment as a whole will often involve making trade-off judgments between different types of environmental impact, and these judgments will often be influenced by local considerations.

Although an attempt is made to address some of these issues, it is not possible for them to be considered fully in this document. The techniques and levels presented in Chapter 5 will therefore not necessarily be appropriate for all installations. On the other hand, the obligation to ensure a high level of environmental protection including the minimisation of long-distance or transboundary pollution implies that permit conditions cannot be set on the basis of purely local considerations. It is therefore of the utmost importance that the information contained in this document is fully taken into account by permitting authorities."

# 3. Fundamental concepts

## 3.1 BAT-associated Emission Range and Emission Limit Values

Different wording can be used to express the concept of performances associated with BAT. In the Waste Incineration BREF, the IPPC Bureau uses BAT-associated Operational Emission Levels. In other BREFs, the usual term is BAT-associated Emission Levels. It was however recognised that the “L” of levels is easily mistaken for "Limit", which is not consistent with the real purpose.
The emissions are expressed as ranges in the BREFs. Cefic has therefore suggested to use the wording “BAT-associated Emission Ranges” which, in our view, best fits the concept of performances resulting from the application of one particular BAT in different plants, different countries i.e. different local conditions. If we want to be still more general and include the range of consumption (raw material, energy) associated with a BAT, we can speak of **BAT-associated Performances Range, BATAPeR**.

The association of ranges with environmental performances is justified by the variability of measured performances for a given process in a set of local conditions (variation in raw material composition, performance of catalysts, cleanliness of the equipment, etc...), by the plant to plant variability for similar equipment, (cooling conditions, etc...) and by the design variations for the same generic equipment (e.g. condensing the same gaseous stream with a 100 $m^2$ heat exchanger or 500 $m^2$ are both operations called cooling but resulting in differing performances). An additional factor is the quality/purity level of the finished product, which is a market-driven constraint.

Emission Limit Values can take the form of emission limits fixed for a particular permit or a general limitation imposed by a regulation (Waste Incineration, Large Combustion Plant etc.). Compliance is generally required with different modality according to the country, resulting from differences in measurement requirements and criteria for compliance.

It is essential that the reader understands the following:

- BATAPeRs and ELVs are of a different nature
- The BATAPeRs reported in the BREF are operational performance ranges that are believed to be generally achievable through the application of BAT; they often result from monitoring data of plants expressed as averages (month, year...)
- ELVs are the levels set in permits and/or national legislation. They are regulatory control values. Compliance with ELVs of the type set in permits necessarily results in operational levels below those ELVs. It is therefore incorrect to equate ELVs and BATAPeRs
- Across the EU 25, ELVs are set and enforced in different ways (daily average, monthly average,… compliance 100% of the time, 95% of the time….)
- It is possible to have ELVs within the BATAPeR but IPPC Directive does not make it mandatory. Depending on the local conditions and stability of the

process, the ELV can correspond to emissions significantly higher than the BATAPeR
- The operator should not accept without justification the lower limit of BAT-associated Performances Range as basis for the determination of ELVs.

A detailed discussion on performances and ELVs can be found in Annex 1.

It is also useful to consider the following extract from the chapter 5 introduction to the BAT conclusions (standard for each BREF):

"Where emission or consumption levels "associated with best available techniques" are presented, this is to be understood as meaning that those levels represent the environmental performance that could be anticipated as a result of the application, in this sector, of the techniques described, bearing in mind the balance of costs and advantages inherent within the definition of BAT. However, they are neither emission nor consumption limit values and should not be understood as such. In some cases it may be technically possible to achieve better emission or consumption levels but due to the costs involved or cross-media considerations, they are not considered to be appropriate as BAT for the sector as a whole. However, such levels may be considered to be justified in more specific cases where there are special driving forces."

### 3.2 BAT versus ALARA and other concepts

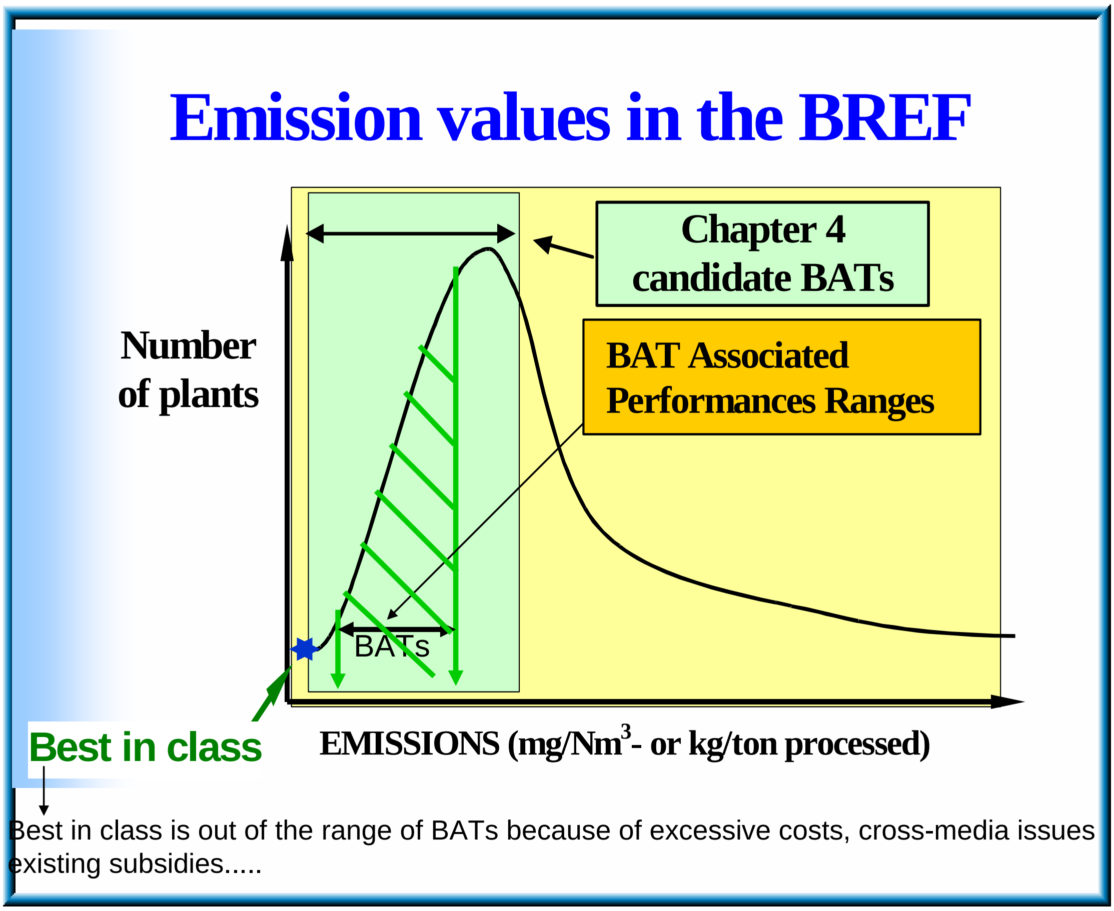
Nothing prevents Member States from implementing the IPPC Directive with more stringent standards. They can extend the scope (the range of industry covered by the Annex 1 of the Directive) or lower the capacity threshold.

Sometimes, basic concepts may be modified in the transposition of the Directive into Member States. One example among others is the ALARA concept.

ALARA stands for "As Low As Reasonably Achievable". The question is: what is reasonable? For instance: what if the emission reduction is not needed from an environmental point of view, e.g. if the emission does not cause any concern related to national or regional environmental quality standards? The concept of "reasonable" is open to a wide range of interpretation.

Another concept is "the best ever" or "the best in class" where there are attempts to use one particular plant with exceptional performances as a rule. This is not the spirit of the Directive. This "best ever" solution may have been implemented because of other drivers (subsidies, demonstration plant, ...) and be uneconomical for the sector.

The following picture should clarify these concepts




- Chapter 4 of a BREF describes the "Techniques to consider in the determination of BAT", often called "candidate BATs"
  These techniques are generally used in the major part of the industry. They are neither the "outdated techniques" nor the "best in class"
- Chapter 5 of a BREF describes the "BATs" (and the corresponding ranges of emissions)
  A few techniques are considered as BATs i.e. technically and economically viable for the sector (a sector is, for instance, the Large Volume Organic Chemicals sector or the Organic Fine Chemicals sector etc.)
- As low as technically possible or "best in class": techniques which, due to cost, scale or cross media issues, are not deemed BATs. Some may be considered as Emerging Techniques and consequently included in chapter 6.

### 3.3 Sectoral BAT and Site Specific BAT

Annex IV of the Directive deals with the "considerations to be taken into account generally or in specific cases to determine BAT…".
This is the reason why we use the wording

- "Sector specific BAT" or "sectoral" BAT when referring to the "general" BAT defined in the BREF

- "Site specific" or "local" BAT when referring to the technical solution selected for a particular plant in the context of an IPPC permit. A more exact wording could have been "local best environmental option" but it is easier to use "site specific BAT". The meaning however is identical.

The selection of BAT in the BREF is, in principle, based on an analysis of the costs and benefits relative to the entire sector. These BATs are also supposed general enough to be deemed BAT across EU. Very often, they result from the gathering of industry experience across Europe, and the fact that they are currently applied is considered as an implicit positive result of a cost effectiveness analysis and of a technical/economical viability assessment for the sector. As a result it is also clear that any attempt to be too detailed or prescriptive while determining BATs in BREFs is against the spirit of the Directive.

When assessing the applicability of such sectoral BAT in a given installation, the following aspects have to be duly considered – as recommended by the Directive itself[3]:

- The technical characteristics of the installation concerned
- Its geographical location
- The local environmental conditions

The Directive recognises that it is totally impossible to describe BAT for all substances (30.000 chemicals!) at any location and considering any circumstance across Europe, and it is not the aim of the BREF to do so. The most appropriate technique may indeed depend on local factors. These local factors or conditions can affect both the environmental impact of a technique as well as the costs of its implementation, which cannot usually be determined at the sector level. On top of that there is always the requirement of the Directive to avoid any prescription from Competent Authorities regarding the technique to use[4]. **Simply said: the operator has a duty of results and not a duty of means.**

The operator may face the following situations (derived from the UK IPPC Guidance Note – see reference 3):

1. The installation already meets (or is planned to meet when new) BATAPeR,
   - Using one of the techniques described as BAT in the BREF[5]. In this case the permit requirement is straightforward. It is worth mentioning that often the BREF proposes more than one BAT or suggests a combination of techniques leading to BAT.
   - Not using the techniques described as BAT in the BREF. In this case the operator will have to verify that his choice meets the performances associated with the BAT and to justify the choice of a technique different from what is proposed in the BREF. Let us call this technique a **Site Specific BAT**.

[3] Art.9.4

[4] Art.9.4

[5] If there is more than one BAT proposed in the BREF, the operator needs to make a selection, often on the basis of economical considerations or cross-media issues.

2. The installation does not meet BATAPeR. Then the following approach is recommended:
    a. There is a justification for departing from the BATAPeR because of local considerations, for instance cross-media issues or age of the plant etc... This may also result from local EQS[6] considerations. For instance, emissions do not meet sectoral BATAPeR but the corresponding environmental impact is so inferior to the EQS that the Competent Authority may agree on emission limits less stringent than the sectoral BATAPeR. This is especially relevant when emissions of different substances are considered, and when it is necessary to discriminate between what is fundamental for the determination of BAT and what is negligible. We also need to remember that Art. 1 of the Directive speaks of a "high level of protection" and not "the highest". Another case may arise from economical considerations: for instance the operator may operate to a standard which is close to the BATAPeR but full compliance would require disproportionate costs compared to the emission reduction obtained. It is clear that a detailed and in-depth analysis of the cost of techniques compared with the achievable emissions will be necessary.
    We will still call the technique selected in these circumstances a **Site Specific BAT**.
    b. There is no such justification: in this case the Operator needs to meet the BATAPeR using techniques as defined in the BREF or any other technique, in other words using a **Site Specific BAT** as in § 2 above.

3. There is no sectoral BAT or no BREF. In this case, the experience of the operator, comparison of similar processes, horizontal BREFs, and cost effectiveness analysis (see chap.6) could help the operator to propose and justify the selection of the best option. We can again consider it as a **Site Specific BAT**.

**NOTE (1)**
Costs and performances in local conditions could deviate from those displayed in the BREF document for a lot of reasons:
- when adding a piece of equipment to an existing plant: it usually costs much more compared to grass root construction (decommissioning, rebuilding, structure modification, pipe racks modifications, loss of production etc.)
- when equipment is added to debottleneck the plant capacity while improving its environmental performance; this may not be applicable to another plant because the same equipment will not provide an actual debottlenecking (e.g. the bottleneck is somewhere else)

**NOTE (2)**
Once a sectoral or site specific BAT has been selected, the question raised is the following: is the resulting environmental impact consistent with the local EQS, and if not what are the options? This question will be addressed in chapter 4.

[6] Environmental Quality Standard – see section 3

**NOTE (3)**
In assessing the impact on the EQS, it is important to also include the effect of emissions from other sources (industry, traffic, agriculture and natural background) as explained further in this note.

### 3.4 "Vertical" and "Horizontal" BREFs

We call "vertical" a BREF dedicated to the production of specific substances like Large Volume Organic Chemicals. "Horizontal" BREFs are dedicated to an issue common to a substantial part of the industry, for instance "Emissions from Storage", "Common waste water or waste gas treatment" etc.

Horizontal BREFs describe techniques which are commonly applicable to the whole spectrum of the chemical industry. As a result, only generic conclusions are derived in these BREFs, which de facto could not take into account the specific characteristics of the manufacture of a substance (e.g. ethylene from steam cracking) or a type of industry (Organic Fine Chemicals)

The understanding is as follows:

- When a substance or a family of substances has been covered by a vertical BREF and where BATAPeR are available, those values prevail. It is recognised that the vertical BREF takes into account the specificities of the industry producing this substance
- when there is no such BATAPeR available in a vertical BREF or when there is no BREF about a particular substance:
  - the experience of the operator is the first source for determining the site specific BAT; cost effectiveness analysis may help to substantiate it
  - there may be a way to refer to similar substances or families described in a vertical BREF (obviously taking into account the differences)
  - there is a possibility of relying on a horizontal BREF.

### 3.5 Split views

Regularly, some of the statements in a BREF are challenged by "split views", especially in the chapter dedicated to BAT conclusions (generally chapter 5). The effect of the "split views" is to attract the attention of the readers (operators and permit regulators) on which specific issues consensus was not reached within the Technical Working Group in charge of developing this BREF. Consequently, while a statement without a split view is strong and considered as granted by the Technical Working Group of European experts, a statement with a split view is weakened, and may lead to discussions - the situation being different according to the source of the split view (MS or Industry).

# 4. EQO and EQS

## Environmental Quality Objectives – Environmental Quality Standards

An Environmental Quality Objective is an environmental status attributed to or targeted at certain media (air, water, soil,...). EQOs are expressed in qualitative terms (e.g. compatibility of a certain use of the media) which reflects a certain level of ambition (e.g. good chemical status for all surface waters by 2015).

These objectives can originate from European directives or national programmes or be defined on purpose in local environmental programmes. Not all of them correspond to an obligation of achievement.

In the following parts we will only consider quality objectives that are associated with an obligation of achievement.

An environmental quality standard (EQS) is, for a given substance, the maximal allowable concentrations of that substance in the receiving media which is supposed to correspond to the achievement of the environmental objective. As environmental effects are primarily chronic effects, EQSs have to be verified as an average over a long period of time, usually an annual average.

It is important to bear in mind that there is no direct connection between concentration in an effluent and concentration in the receiving media.

EQSs are usually defined in the framework of UNO recommendations (e.g. WHO guidelines for drinking water...), European or national legislation. When no EQS is fixed for a substance, the general health protection and ecosystem protection objectives can be used to define limit values which are fit for the purpose.

For human health protection it is necessary to define a maximum average daily intake for a targeted person and to attribute (based on accepted scenarios) a maximum proportion of this daily intake to the exposure tract under investigation (e.g. maximum intake allowed through respiratory tract). When this maximal quantity is known as well as the quantity of media (air, water, food...) absorbed on a daily basis, the derivation of the corresponding maximum concentration in the media is straightforward.

For protection of ecosystems maximum concentrations in surface waters can be derived by using a European accepted method called the technical guidance document (TGD). The outcome of the calculation is a Predictable No Effect Concentration (PNEC), which plays the role of EQS. Comparable values can be derived for soil, sediments and biota. Although it would make sense, calculating such values for air is not customary at present.

Since in many cases the calculation takes account of a local scenario, a validation by authorities is often requested.

**NOTE**

- As already said, Environmental Quality Standards are quality requirements for receiving bodies - not for effluents.
- Quality standards are maximum allowable concentrations in the receiving media (air, water soil), defined to protect human health and ecosystems.
- They do not presuppose any verification of the technical or economic feasibility of techniques to achieve them.

## 5. Quantify local impact

The Directive specifies that not only BAT (sectoral or site-specific) need to be applied but that "no significant pollution is caused". This requirement is obviously addressing the local level only and entails an environment impact analysis more or less detailed according to the sensitivity of the local environmental conditions.

Emissions are, by definition, taken at the boundary of an installation and ELVs fixed by the permit are related to these emissions. However it is important to distinguish between emission and actual environmental impact of the emission on the environment. To simplify things, let's consider point sources only e.g. a stack. Evaluating the actual environmental impact at a given location needs to take into account the dispersion (and more generally the fate of the pollutants in the environment) and any relevant local conditions to establish the environmental impact to be compared to a maximum level fixed by the EQS. Note that BATAPeRs are very often expressed in kg/ton of product. The impact calculation is therefore the only way to transform flow into concentration for comparison purposes.

In this note the word "impact" means the concentration resulting from emissions into a receiving environment and the ultimate aim of the exercise is to compare a predictable or measured value in the receiving media against the EQS.

The problem of local environmental effects is addressed in the REF document on Economics and Cross-Media Effects (reference 2), chap. 2.6.4:

"Across Europe, there are significant variations in receiving environments, in local ambient concentrations of pollutants and in environmental priorities. For any individual process, the assessment of likely impacts of the proposal may require detailed dilution and dispersion modelling of individual pollutants. The dilution factors below can be used as a quick screening tool to evaluate which pollutants might need to be modelled in more detail in local situation……..

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

$$\text{Dispersed Concentration} = \frac{\text{emission concentration (mg/m3 or mg/l)}}{\text{Dilution factor}}$$

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

- for discharge to water, a dilution factor of 1000
- for discharge to air, a dilution factor of 100 000 (based on discharge from a chimney stack from e.g. combustion plants)

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

If the release does not contribute to a dispersed concentration of greater than 1% of the relevant EQS, or a similar benchmark, then the emission is sometimes regarded as insignificant."

The direct comparison PEC[7]/PNEC[8] value or predicted intake/TDI[9] is only valid when a unique source of emissions exists. In many cases one has to consider the addition of the source under investigation to the impact of other existing sources and in some cases to the natural background. The sum of all is the impact on health or on the environment that has to be compared with the EQS.
When the total predicted or measured concentration exceeds the EQS, reduction measures are necessary and, in some cases made mandatory by air or water directives.

In order to illustrate the approach we have limited the case to one simple isolated installation.

The steps to be followed are:

1. List and locate the emissions and the release points (flow rate, composition, T° if relevant etc.). Statistical considerations may be useful (max, min, average, percentile etc.). Grouping substances may be useful when the detailed composition is not known or irrelevant (e.g. VOC, NOx etc.). In case of confidentiality issues, the analysis needs still to be detailed but the reporting could use grouping or be kept confidential by the Authorities
   In this emission inventory, it may be useful to group similar substances having specific environmental effects like water toxicity, eutrophication, photochemical ozone creation etc. The BREF Economics and Cross-Media Effects is a source of useful information for this purpose. Operator and Authorities should be careful not to mix long range effects and local effects. Long range effects may be an important consideration when establishing BAT at a sectoral level. At permitting level, local considerations should prevail. However contribution to national or regional reduction programmes (see chap.7) such as national emission ceilings may impact the process of determining ELVs.
2. Identify the key environmental issues related to an installation, whether existing or planned. This should be done in relation to the selected techniques, for instance when different options are considered for selecting the site-specific BAT. The BREF may be an excellent source of information.
3. Quantify the impact or how to translate emissions into impacts i.e. to estimate the concentration of emitted substances after dispersion into the receiving environmental media.
   In the case of existing installations, it may be possible to simply measure the concentrations in the environment. In the case of surface waters, it is necessary to sample after the effluent mixing zone and to substract the upstream concentration from downstream measured concentration. This concentration may follow seasonal variations due to high/low flows.

[7] Predicted Environmental Concentration
[8] Predicted Non Effect Concentration
[9] Tolerable Daily Intake

With release to the air the situation is more complex due to meteorological variations at the point of observation. A limited number of point measurements cannot be representative. Only observations over a long period can be. When no representative measurement value is available or in the case of a new emission to come, it is necessary to calculate this concentration at the point of observation (PEC: Predicted Environmental Concentration).

In any case it is necessary to go through the quantification of the incremental value resulting from the considered emission, and to add this concentration to the background concentration. The background concentration is defined as the one observable in the absence of the emission under investigation and can include the natural background concentration and the effect of other point and diffuse sources.

This step of the assessment will extensively use mathematical dispersion models, which take as input the releases to the air and surrounding conditions. It is clear that sophisticated tools should only be used if the importance of the emission justifies it and will not be justified if the emission – under common sense considerations – results in negligible environmental impact. It is recommended that the operator uses models agreed or recommended by the Competent Authority (or justifies why he applies other models).
Simplified models can be very useful to screen options or give orders of magnitude enabling decisions to be taken. As a rule, accuracy is not necessarily the panacea to take good decisions. Examples can be found in the UK Environment Agency Guidance Note IPPC H1[10]:

a) Contribution of air emissions of an installation: according to the height of the release, a dispersion factor is given which allows calculating the concentration of a pollutant starting from the quantity released (in mass per second). This concentration should be added to the background concentration to estimate the total predicted environmental concentration (PEC).
b) Similar approach for surface water: starting from a pollutant concentration in the installation effluent and the flow rate of this effluent, the contribution of the installation is estimated by calculating the dilution factor using the river flow rate, the estuary dispersion rate and the coastal water dispersion rate according to the specific case. Similarly, the concentration after dilution has to be added to the background concentration to calculate the predicted environmental concentration. This can also be measured in the case of a river. Note that for a number of substances, it can be justified to take account of phenomena such as evaporation into air, adsorption onto sediments, biological degradation. Conversely, some new problematic substances may arise from degradation mechanisms and give rise to new problems.

[10] see http://www.environment-agency.gov.uk/business/444217/444663/298441/horizontal/?lang=_e

4. Compare PEC with EQS or compare the impacts of different options.
   The quality objective is reached when and only when the concentration of the substance in the media does not exceed the EQS.

   - Comparison with EQS may be straightforward: in the case of a unique source with no background concentration. If reduction measures happen to be justified, they have to apply to this unique source.
   - In the case of contribution from other sources, exceeding the EQS does not necessarily mean that the source under investigation is to be considered as the origin of the problem.
   - The simplified methodology described above presupposes that all the impact can be limited to the local level. In reality, the long range effects play a role through national or regional programmes aiming at reducing the emission of certain substances. These programmes are then transposed into plant by plant actions whereas in the case of purely local impact, the decisions are totally taken locally.
   - Comparing impacts of different solutions may be intricate, and may necessitate solving cross-media conflicts. There is no magic formula to help and only expert judgement can be used in this exercise. Information on cross-media analysis is available at reference 2 (BREF Economics and Cross-Media Effects). Some useful common sense recommendations can also be found in the UK Guidance Note (reference 3) e.g. more attention should be given to
     a) substances whose PEC is close to EQS
     b) sensitive receptors
     c) PBTs, CMRs substances
     d) Substances subject to national reduction plans

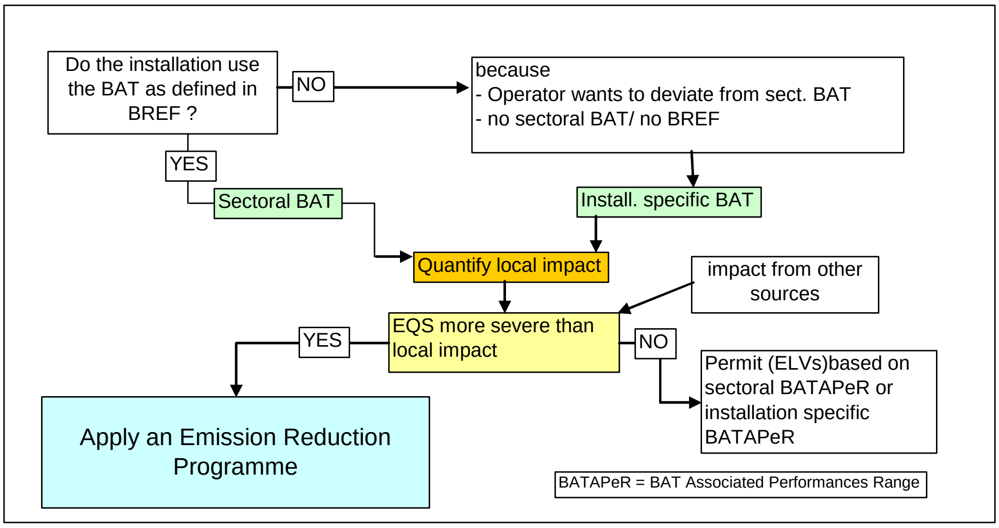
**NOTE (1)**

In the simple case of one source having environmental performances corresponding to BAT, suppose that the resulting PEC value on a particular medium is known (i.e. BAT-associated environmental impact) and compared to the EQS corresponding to this medium.

- Although the techniques developed to improve the environment performances of installations are often driven by an EQS, it does not follow that the environmental impact of BAT-associated emissions will necessarily be equal to the EQS. They will - on the contrary - often be different.
- If an EQS is higher than the PEC value corresponding to BAT-associated emissions, the competent authority will fix the ELV on the basis of the BATAPeR, and no further measures will be necessary.
- If an EQS is lower than the PEC corresponding to BAT-associated emissions, "additional measures shall be required in the permit[11]". This may imply additional abatement devices or process modifications (change of fuel, raw material specifications etc.) and the question for the operator is how to select

[11] IPPC Directive 96/61 EC – Art.10

them to meet the requirements at minimum cost i.e. design an appropriate emission reduction programme. However the economic viability of the installation should be assessed.




When the assessment of the environmental impact and comparison with EQS is achieved, and if the conclusion is that the impact of the installation under BAT/BATAPeR conditions is not sufficient to meet EQS requirements, it is necessary to assess the costs of the different options necessary to reach the EQS.

Methodologies to satisfy EQS requirements at the lowest global cost are developed under section 7 “Emission Reduction Programme”

**NOTE (2)**

Case of Directives relative to a specific sector of the industry (Large Combustion Plant, Waste Incineration, Use of Solvents etc.)

These Directives define ELVs i.e. regulate emissions from plants. In this particular case, a straightforward comparison can be made: ELVs from the Directives against ELVs derived from BATAPeR (from the BREF or from the Site Specific BAT as developed in section 2).

As a conclusion:

- If the ELV from the Directive is less stringent than the ELV derived from the BATAPeR, the competent authority will fix the ELV in the permit on the basis of the BATAPeR and no further measures will be necessary.
- If the ELV from the Directive is more stringent than the ELV derived from the BATAPeR, “additional measures shall be required in the permit[12]”. See Note (1) above.

More stringent regulations may also result from national regulations for certain substances or emissions even in the absence of Directives.

[12] IPPC Directive 96/61 EC – Art.10

# 6. Cost[13] effectiveness

Let's start with an example.

Suppose a person having to travel 50 times per year on a business trip that takes 8 hours by train (difficult connexions) wants to increase his "time efficiency".

Present situation = base case: 1500 EUR/year and 400 hours "lost" per year.
1st solution: use a car at 2000 EUR costs per year and 5 hour trip only i.e. 250 hours "lost" per year
2d solution: use a plane at 5000 EUR costs per year and 3 hour trip only i.e. 150 hours "lost" per year

Let's start from the base case i.e. the trip by train and look at options to improve the situation.

| | Compared to the base case | | | Comparing option n and n-1 | | |
|---|---|---|---|---|---|---|
| | Additional Costs EUR/year | Hours "saved" | Cost effectiveness EUR/h saved | Additional Costs EUR/year | Hours "saved" | Cost effectiveness |
| Car | 500 | 150 | 3,3 | 500 | 150 | 3,3 |
| Plane | 3500 | 250 | 14,0 | 3000 | 100 | 30,0 |

Suppose you "value" one hour saved at 20 EUR.

If the "car" option was not considered, you would probably have concluded that the "plane" is worthwhile since it cost less than 20 EUR/h. The sole fact that the option "car" exists, changes the conclusion. As a matter of fact, the option "plane" is becoming very expensive and cannot be justified. The conclusion is that the car is the best alternative.

This simple example highlights two important points:
1. A technique should be justified not only against the base case, but also against the next best alternative.
2. The option leading to the best environmental performance can be an addition to the next best alternative (for instance a second stage of abatement) or a different option (e.g. a filter instead of a wet scrubber). The methodology is the same.

The example discussed here is comparable to adapting new solutions to an existing plant - for instance abatement systems or Leak Detection and Repair systems - or to comparing various alternatives to a base case for a new plant.

[13] The methodology to use for calculating costs (capital-operational- how to annualise etc.) is described in the BREF Economics and Cross-Media (reference 3).

In the general case, where there are several techniques to be considered, it may be possible to plot a curve of costs against environmental effects. For example, Figure 6.1 shows a curve resulting from plotting the cost versus the mass of pollution avoided.

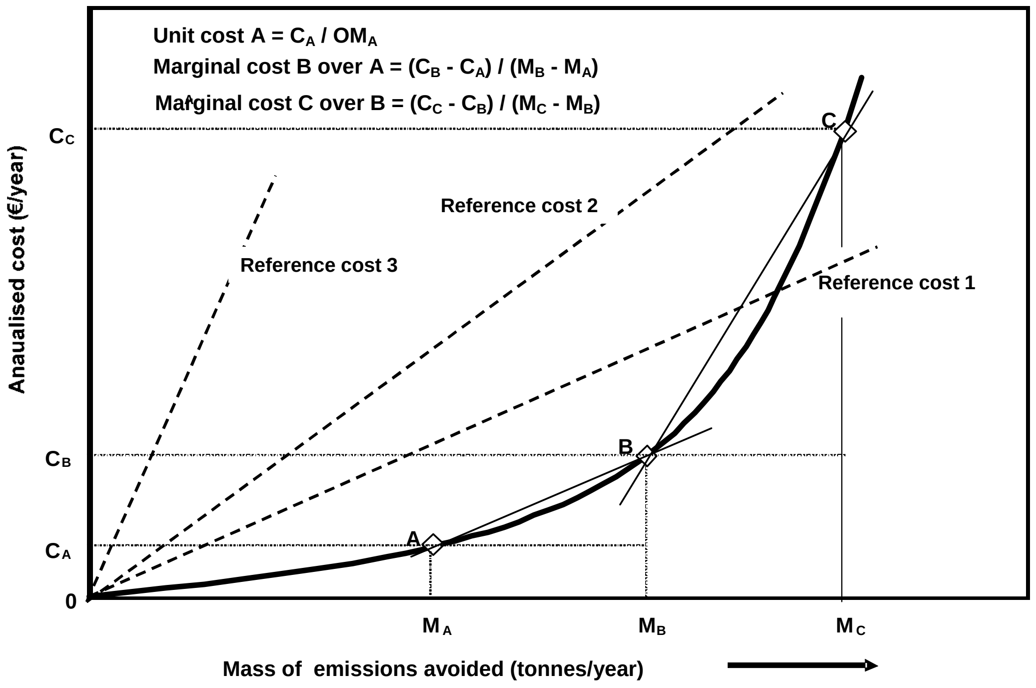



*Figure 6.1: comparing costs against environmental benefit*

Figure 6.1 illustrates how to compare costs against environmental benefits, as would happen in the determination of BAT in a BREF.

A, B and C are different options for an installation which result in different quantities of emission avoided (emissions decrease when moving to the right) and correspond to different annualised costs.
Where these represent a new process, A could represent the base case and B and C different alternatives in growing order of environmental protection.
Where these represent additions to an existing process, A could be the current plant situation, and B and C could be alternative improvement options.

In all cases, the marginal cost-to-environmental improvement ratio (in short, cost effectiveness) of an alternative must be calculated by comparing it with the next best alternative, namely the option that ranks just next to the one being investigated in terms of environmental improvement. Referring to a situation where the environmental improvement consists of lower emission, the cost effectiveness is expressed as a *cost per ton of avoided emission*. This cost/ton is compared to a reference cost. If the cost/ton of the alternative being investigated is lower than the reference cost, the alternative is deemed justified.

Whether dealing with a new installation or with an existing installation that is being modified does not change the way in which the analysis must be conducted. Obviously in case of an existing installation the addition of equipment can incur much higher cost than adding it at the design stage of a new installation (demolition cost, structure cost, piping modification, loss of production...).

Three possible reference costs are represented in figure 6.1 resulting from 3 different situations (e.g. location). Since tons are on the abscissa and costs on the ordinate, the slope of the line representing a reference cost increases with the reference cost value. Higher costs per ton of emission avoided are represented by lines with a steeper slope, therefore reference cost 1 < reference cost 2 < reference cost 3.

Referring to figure 6.1, let's assume that the options B and C represent alternatives to a new installation represented by option A. The question is: should option B or option C be preferred over option A? The answer depends on the reference cost with which costs per ton are compared.
Where the reference cost is represented by the dashed line 1 on Figure 6.1, option B is justified because the slope of the line joining A to B is lower than the slope of the line representing the reference cost 1. In other words, the incremental unit cost (also called the cost differential) of option B versus A is justified because selecting option B instead of A results in a marginal cost/ton which is lower than the reference cost. However, Option C is not justified in this case because selecting option C instead of B results in a marginal cost/ton of C over B which is higher than the reference cost.
If the reference cost was represented by the line labelled reference cost 2, which represents a higher cost/ton than line 1, option B is obviously still justified. However, option C is still not justified because the incremental cost corresponding to selecting option C instead of option B results in a cost/ton which is still higher than the reference cost 2.
In order to justify option C, the reference cost must have at least the same slope as the line BC, as is the case for reference cost 3.

Reference costs may not be available in all situations for all type of emissions. However the methodology is still valid to prioritise and rank the different options, in particular to apply a series of emission reduction measures at lowest costs.

Annex 2 provides a few examples developed to illustrate the above concepts with practical considerations.

The approach set out here is not always accepted by regulators, who tend to only consider evaluating an environmental improvement on the current situation (or the base case for new construction). However, this approach is consistent with project evaluation practice in general. Moreover, the cost curves developed by IIASA[14] (as a basis for establishing the ceilings under the National Emission Ceilings Directive) also indicate incremental costs. Therefore the method is also consistent with the EU policy basis. And finally, it should be noted that for new projects, there is no existing

[14] IIASA : International Institute for Applied Systems Analysis, Laxenburg, Austria

situation and, therefore, the definition of the "base case" is arbitrary; so this is the only possible approach for new investments.

**Cost effectiveness**

This concept, developed above in this section, is based on the ratio between the cost of an action and the result of this action - for instance an emission reduction. Usually, the cost is an annualised cost[15] and the emission reduction is an annual emission reduction. Cost effectiveness is the ratio between them and is expressed in € per ton of pollutant avoided.

**Marginal cost**

When a few options are available - either complementary or as parallel options - the marginal cost expresses the ratio between an increase in costs and an increase in emission reduction compared to the next best alternative. In other words, the marginal cost is defined as (delta annual cost) divided by (delta annual reduction of emission) and is expressed in € per ton (or €/kg) of reduced emission as shown in the former section.

**Reference cost**

Reference costs are costs per unit of emission reduction that can be used as a reference to define whether an emission abatement measure is justified. If the marginal cost of the emission reduction measure is lower than the reference cost, the measure is considered to be justified, otherwise it is not.

**Cost benefit analysis**

In the cost effectiveness analysis, the benefit is considered as an environmental improvement like an emission reduction (decrease in the annual quantity of pollutant). A cost benefit analysis on the other hand, is an attempt to monetarise the environmental improvement. This is not a financial benefit for the operator but rather a “monetarised” benefit for the environment. There are some economic theories which could allow an economic evaluation i.e. the virtual costs due to the different impacts on health and environment on the basis of factors like the price of an extra year of life, or damage to crops etc. These estimates are of course subject to an important margin of uncertainty. These costs are often called “external costs”.

Starting from a defined initial situation, the sum of the treatment costs (abatement costs, for instance) considered as “internal costs” borne by the operators and environmental costs borne by the public (external costs) correspond to a global economic burden for the whole of society.

The cost benefit analysis aims to compare costs borne by the operator to improve the environment with the “avoided” costs for the public resulting from this improvement. According to the theory, the global minimum is reached when internal costs are equal to external costs.

[15] Annual costs take into account (1) investments spread over the years with the classical depreciation formula, function of interest rate and number of years investment lifetime (2) operating and maintenance costs (3) if any, the specific benefits from the measure for instance energy or raw material savings – see reference 2 (REF E&CM) chapter 3.

**Reference prices**
In some countries there are values attributed to some pollutants, for instance, in Sweden for NOx, VOC etc. in terms of currency per t of pollutant avoided. These values are used to set limits to investments (annualised) and operating costs. In the case of Sweden, they are used as a tax allocated for a specific pollutant (for instance 4 €/kg for NOx) from which annual costs – for the abatement of this specific pollutant - may be deducted (limited to 4 €/kg in this case).

**Acceptable costs**
This notion is used in the IPPC directive (but not only there) in relation to "an implementation economically viable for the sector[16]". The sector here is considered as the producers of a same substance (soda ash producers) or family of substances technically related (fertilizer producers). These acceptable costs are defined starting from a group of installations representative of the sector and showing environmental results from techniques which may lead to their being deemed BAT. The hypothesis is that, for these installations the costs have been considered acceptable since they have implemented these techniques. This is an implicit verification of the cost acceptability.
Installations showing exceptional performances are excluded from this analysis, what we have called "best in class" in a former section (see page 7).
These costs are expressed in annual total costs or, preferably, in costs per unit of pollutant abated i.e. in terms of cost-effectiveness. They address all installations of a sector but do not take into account the financial situation of a specific operator.

**Cost acceptable to an individual operator**
It may happen that an action/technique acceptable to the whole sector is impossible for a specific operator to bear, in the present economic context, for a specific installation and could jeopardise the existence of this installation. This is clearly a conflict between the different pillars of sustainable development.
The Competent Authority must take into account the consequences of certain constraints which are imposed to improve the environment and the concerns of this Authority must go beyond the simple literal application of regulations. Measures like time-for-implementation (which is mentioned in Annex 4 of the IPPC Directive), compensations, and derogations can be tools for reconciling economic reality with observance of the spirit of the regulations.

[16] IPPC Directive 96/61/EC – Art.2.11

# 7. Emissions reduction programme

A selection of reduction measures and the implementation of an emissions reduction programme can be necessary in several situations:

- A defined quality objective cannot be reached because the EQS (or PNEC) is already exceeded,
- This objective will not be reached if a new emission resulting from a new project is authorised,
- A national or local reduction programme has been defined (e.g. emission ceilings, reduction of certain substances in given water body of x %...).

In such a situation, the first element of calculation will be the reduction quantity taking account of the expected evolution of all sources ("business as usual" scenario). The "business as usual" scenario will take into consideration the effect of regulations already enacted but not yet applied.

**General considerations**

If an EQS is already exceeded, or may be exceeded as a result of an additional contribution from an IPPC activity, account of further control measures needs to be taken. Going beyond BAT (which is clearly imposed in this case by the IPPC Directive) needs to be practical and reasonable.

Suppose a plant P is discharging pollutant A (e.g. benzene) to a receiving medium (e.g. river) where the EQS for pollutant A is not achieved. The following questions need to be asked:

- Is this discharge the only reason why the river does not achieve "good quality status"? Most European rivers face more important (structural) problems related to other WFD parameters i.e. Nitrate, Morphology,

- Are there other sources discharging pollutant A (including diffuse sources) and what are their relative importance? The likelihood of remedial action elsewhere has to be taken into account. Where a new installation would only make a minor contribution, it will normally be more desirable for Authorities to consider controls on other major sources of pollution rather than imposing excessive costs or refusing a Permit.

- If the discharge of plant P dominates, are there, in the portfolio of BATs, techniques which can be used for reaching the reduction objectives? We may have:
    - No technique
        - A new technique has to be developed which needs
            - Time (to create and scale-up new techniques; supporting pilot studies is of particular importance)

  - Money (e.g. subsidies)
  - Derogation during the meantime
- A technique exists but is not economically viable
  - Make it economical (subsidiaries, de-taxation)
  - Relax a little some cross media effects constraints (e.g. more energy, more waste produced to achieve the desired concentration in the aqueous effluent)

**Practical methodology when suitable techniques exist**

In the simple case where techniques exist for applying an emission reduction programme, different methodologies can be used to select the appropriate reduction measures, with different merits.

In order to achieve the lowest total reduction costs, the following methodology is proposed:

1. Identify the most promising possible emission reduction possibilities (point/channelled and diffuse sources) supplementing those already applied
2. For each option:
   a. Estimate the pollutant reduction flow resulting from the action
   b. Estimate the transfer factor from the source to the receiving body (dispersion, dilution factor, evaporation, stripping, biodegradation etc. according to the media air, water, soil)
   c. Derive the net pollutant flow contribution to the receiving body
   d. Calculate the total cost of the action (investments and operating costs – preferably using methods defined in the BREF Economics and Cross Media Effects – reference 2) and the cost per unit of pollutant avoided
3. Rank the available options according to increasing specific reduction costs. Available options mean options accessible at reasonable cost
4. Select the minimum list of actions allowing the emission target to be reached and corresponding to the lowest cost per ton of pollutant avoided.

The methodology is illustrated by Figure 7.1. below.

The curve represents **marginal costs** versus tons of pollutant avoided. The curve is built by ranking the techniques by increasing order of marginal cost. Taking as an example fig. 6.1, the first point would be option A with marginal cost $C_A/M_A$, followed by option B with marginal cost $(C_B-C_A)/(M_B-M_A)$, followed by option C with marginal cost $(C_C-C_B)/(M_C-M_B)$.

If the EQS corresponds to an elimination of 4.7 ton/year of pollutant Z, the corresponding cost is found at 3.5 kEUR/t. And this is the value to be used as reference cost in figure 6.1 to know which option to select.

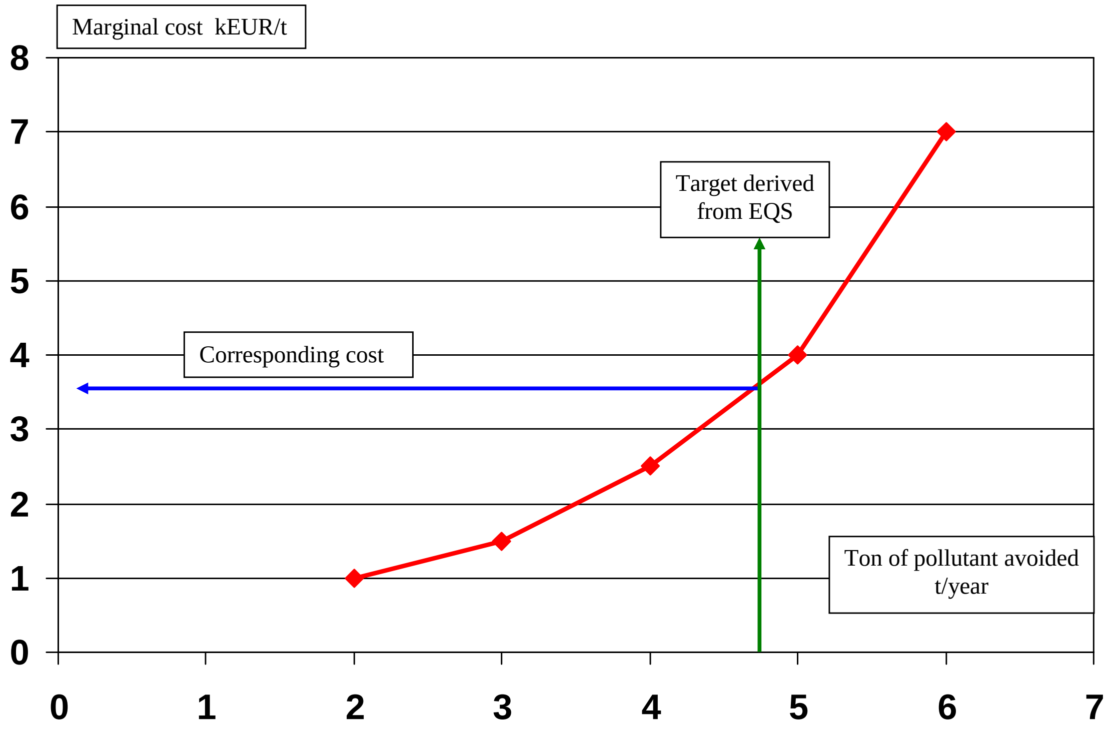



*Figure 7.1: Cost curve – Marginal cost versus tons of pollutant avoided*

**NOTE**

This is not the sole method for selecting a solution. Other criteria than cost minimisation may govern the decision process.

Produced by the Cefic IPPC Working Group
June - 2005

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# 8. References and Glossary

## References

1. "IPPC the new permit policy" Cefic Guidance Document by JM.Demoulin (available at jmd@cefic.be)
2. BREF Economics and Cross-Media Effects – Draft September 2003 (available at http://eippcb.jrc.es/pages/FActivities.htm)
3. UK Environment Agency Guidance Note IPPC H1[17]

## Glossary

| | |
|---|---|
| ALARA | As Low As Reasonably Achievable |
| BAT | Best Available Technique |
| BATAPeR | BAT-associated Performances Range |
| BREF | BAT REFerence document |
| CMR | Carcinogenic, mutagenic or toxic to reproduction. |
| ELV | Emission Limit Value |
| EQO | Environmental Quality Objective |
| EQS | Environmental Quality Standard |
| IPPC | Integrated Pollution Prevention and Control |
| LCP | Large Combustion Plant |
| NOx | Nitrogen oxides |
| PBT | Persistent, bio-accumulative and/or toxic chemicals. |
| PEC | Predicted Environmental Concentration |
| PNEC | Predicted No Effect Concentration |
| TDI | Total Daily Intake |
| TGD | Technical Guidance Document |
| VOC | Volatil Organic Compounds |
| WFD | Water Framework Directive |
| | |

[17] see http://www.environment agency.gov.uk/business/444217/444663/298441/horizontal/?lang=_e

# 9. Annexes

**Annex 1**

**BAT ASSOCIATED PERFORMANCES RANGE (BATAPeR)**

Environmental performances should be described by ranges of values and not by a single value.

To simplify things, let us refer to a theoretical case of a technique and its related process, with only one emission, say to the atmosphere, from one single stack, with constant flow rate V (m3/h).

While the environmental performance can be characterized by an interval within which all instantaneous (concentration) emission values are included, another way, although less effective, to describe performance, is to indicate an upper (concentration) limit (UL), not exceeded by **any** concentration value that may be detected.

Assuming that the total emission adequately represents the environmental impact, it is represented by $V * C_{av} * T$ , for example in t/yr, if T is the yearly running hours and $C_{av}$ is the average concentration in the year of interest.

If the emission trend is not constant, or it is not in a narrow range:
- many measures may be needed to get a reliable concentration average
- the interval width, suitable to describe the performance, will increase
- a higher upper limit UL (not exceeded by **any** concentration value) will be needed to describe the performance (to be compared to the value of $C_{av}$)

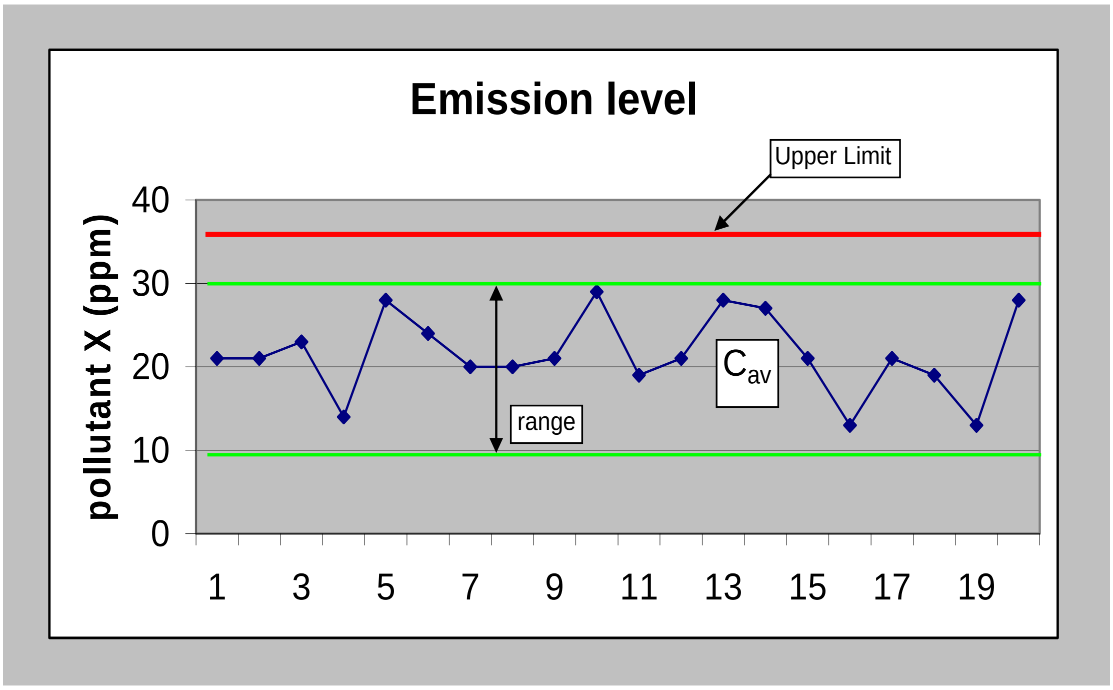
So, the use of upper limit would give a poorer approximation of performance (assessing the environmental impact as V * UL * T), because of:

(1) $$V * UL * T > V * C_{av} T$$

And even, in the case of high variability:

(2) $$V * UL * T >> V * C_{av} T$$

The situation is even dramatically worst in the case of batch operations.




In general the measurement of the actual performance involves some uncertainty; therefore a "safety margin" should be built in to define the UL, causing a further increase in its value.

In other words, the use of UL (to describe a performance) leads to an overestimate of the environmental impact. High variability and necessary safety margin can lead to a very severe overestimate, even in the case of the same average concentration.

In conclusion:

1. For a given performance, the environmental impact is given by average concentration
2. The use of "UL method" to describe performance (instead of average concentration), is always less appropriate and leads to overestimate of environmental impact (see (1) and (2))
3. If the emission trend is regular or constant, and reliably foreseeable, the UL value will be closer to $C_{ave}$, and so its use will be "less inappropriate", and "less ineffective" in assessing environmental impact
4. If the variability of emission trend increases, with the same average concentration, a (much) higher UL will result, with a consequent increase of environmental impact overestimate (using UL instead of $C_{av}$ )

If we consider the role of ELV in a permit, it has the same characteristics as the UL previously described, with an **additional reason for safety margin**, namely that the ELV has the function of **threshold for sanctions (** ELV > UL).
What has been said explains the limitations of assessing an environmental performance, and the environmental impact, starting from the knowledge of ELV: in

different cases, a specific ELV can be associated with emission trends with very different average concentration (and so also environmental impact), depending on different data dispersions, and the degree of confidence over their forecast. In other words, a lower ELV does not necessarily indicate a lower average concentration.

Now, let us come to the practical content of BREF documents, where environmental performances associated with BAT can be found, expressed in ranges. The classical task for the permit writer is to determine a possible ELV for the IPPC permit, starting from the "emissions range associated with BAT" he finds in a BREF (ELV is not defined by the BREF).

These emission ranges are the result of the collection and the comparison of plant performances considered in the information exchange. Each of the single values that make up the BAT range has to be understood as $C_{av}$ value of a "plant participating in the information exchange".

From the regulator's point of view, the lower values of the BAT range are more appealing (closer to the best achievable performance, which is something different from BAT). However, once it has been pointed out that all the values in the BAT-associated performance range (not only the lower ones) allow a technique to qualify for a permit, the possible choice of a specific value in the BAT range corresponds to a $C_{av}$ value. Assuming the chosen technique is described by a specific $C_{av}$, it does not follow that an appropriate ELV is very close, or even equal to $C_{av}$, because of what has been said on the emission trend in time (emission data expected variability, reliability of their forecast, safety margin).

In practical life, we have to consider the ELV (compliance limit), the guarantee of the equipment supplier and/or the safety margin of the engineering calculations and the current performance achieved, in normal routine operation.

In a hypothetical example, if the ELV for pollutant X is set at 10 mg/Nm3, a supplier of a particular technology may, as part of their equipment supply contract, choose to provide a performance guarantee of in the region of 7 - 8 mg/Nm3. In such a situation the plant might then typically operate at 1-5 mg/Nm3 with some transient variations above this.

As an illustration of this relationship, we have the following actual example: the ELVs for dust, given in the permit of two municipal waste incinerators in one MS, are 25 and 15 mg/Nm³ (½hr average) respectively, whereas the measured ½ hr average operational dust emissions are 2.1 (range: 0.5 to 9.1), and 0.8 (range: 0.0 to 12.6) mg/Nm³, respectively. As can be seen, all average emissions are close to the lower levels of the measured ranges and in all cases far below (by a factor 10 to 20) the ELVs. (Waste Incineration BREF)

**Annex 2**

## EXAMPLES

### 1) HF Abatement in Hydrofluoric Acid production

Source: Reference Document in the Large Volume Inorganic chemicals, Ammonia, Acids and Fertiliser Industries (European IPPC Bureau – IPTS[18] – JRC[19] – Seville/Spain), March 2004
Major contributor for HF: CTEF[20] January 2000

### 2) Fugitive emissions in a steam cracker

Source: CITEPA[21] (Paris) Nov.2003 in the framework of UNECE[22] EGTEI[23] studies.
Major contributor to this study on fugitive emissions: UIC[24] (Paris)

### 3) NOx reduction in a municipal waste incinerator

Source: Reference Document on Economics and Cross-Media Effects (European IPPC Bureau – IPTS – JRC – Seville/Spain), November 2004
Major contributor: Dutton (UK Environment Agencies)

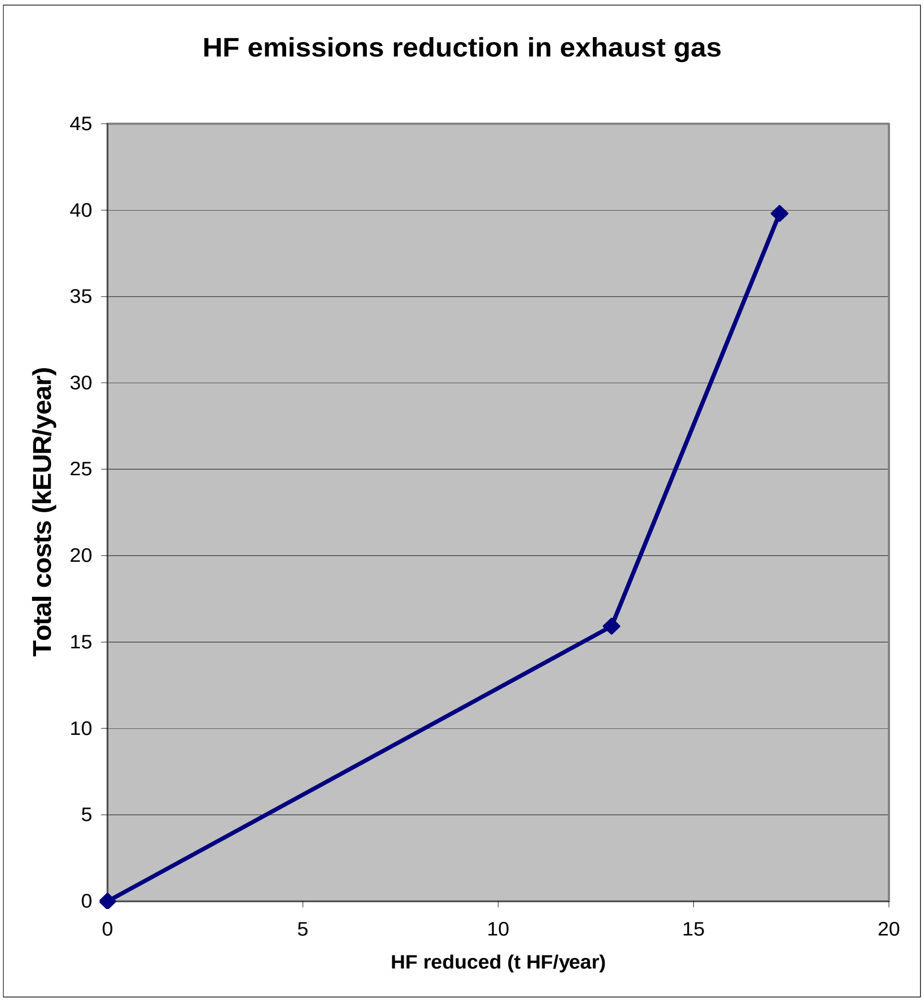
[18] Institute for Prospective Technological Studies
[19] Joint Research Centre
[20] Comité Technique Européen du Fluor
[21] Centre Interprofessionnel Technique d’Etude de la Pollution Atmosphérique
[22] United Nations Economic Commission for Europe
[23] Expert Group on Techno-Economic Issues
[24] Union des Industries Chimiques

# 1. HF ABATEMENT IN HYDROFLUORIC ACID PRODUCTION

Reference installation: HF production line with an exhaust gas flowrate of 100 m3/h
The challenge concerns the selection of an abatement system for HF contained in the exhaust gas
The problem is to analyse 2 possible options for reducing HF emissions
Option 1: Base case - no abatement
Option 2: single stage absorption with water
Option 3: double stage absorption (water + alkaline)
Parameter for annualisation: rate 8% duration 10 years

| Reduction Measure | Gas flowrate m3/h | HF content mg/m3 | Investments EUR | Annualised Investment EUR/year | Maintenance cost 5% | Total cost EUR/year |
|---|---|---|---|---|---|---|
| Option 1 | 100 | 25 | | | | |
| Option 2 | 100 | 10 | 80.000 | 11.922 | 4000 | 15.922 |
| Option 3 | 100 | 5 | 200.000 | 29.806 | 10000 | 39.806 |

| Reduction Measure | Total emissions ton HF/year (8600 h/year) | Compared to the base case Option 1 | | | Comparison option n with option n-1 | | |
|---|---|---|---|---|---|---|---|
| | | Total cost EUR/year | HF emission reduction ton HF/year | Cost effectiveness EUR/ ton HF reduced | Delta cost (EUR/year) | Delta HF (t HF/y) | Cost effectiveness EUR/ ton HF reduced |
| Option 1 | 21,5 | 0 | 0 | | | | |
| Option 2 | 8,6 | 15.922 | 12,9 | 1234 | 15.922 | 12,9 | 1234 |
| Option 3 | 4,3 | 39.806 | 17,2 | 2314 | 23.884 | 4,3 | 5554 |



## Comments

Let's call the point representing option 1 (no abatement: 0,0) : A, the point representing option 2 : B and option 3: C.
The question is: should option 2 or option 3 be preferred over option 1? The answer depends on the reference cost with which costs per ton are compared.
If the reference cost is for instance 1300 EUR/t, option 2 is justified because the slope of the line joining A to B is the cost-effectiveness of option 2 versus option 1, 1234 EUR/t which is lower than the 1300 EUR assumed for reference cost. In other words, the cost differential of option 2 versus 1 is justified because selecting option 2 instead of 1 results in a marginal cost/ton which is lower than the reference cost. However, option 3 is not justified in this case because selecting option 3 instead of 2 results in a marginal cost/ton of 3 over 2 of 5554 EUR/t which is higher than the reference cost.
If the reference cost was 2500 EUR/t, the comparison with option 1 (2314 EUR/t) gives the impression that option 3 should be selected. However, option 3 is still not justified because the incremental cost required in selecting option 3 instead of option 2 (5554 EUR/t) results in a cost/ton which is higher than the reference cost 2500 EUR/t..
In order to justify option 3, the reference cost must have at least the same slope as the line BC, for instance 5600 EUR/t.

## Scenarios

We can investigate the case of different inlet concentrations of HF in the exhaust gas before abatement. If the scrubbers are properly designed, the concentrations of HF outlet stage 1 or stage 2 are approximately the same as in the base case i.e. 10 and 5 mg/m3 respectively.
The results are shown in the following table

| SCENARIOS: for different HF inlet content | | | | | |
|---|---|---|---|---|---|
| HF inlet content | | mg/m3 | 25 | 50 | 100 |
| Option 1 to 2 | Delta Cost | EUR/yr | 15.922 | 15.922 | 15.922 |
| | Delta HF | t HF/yr | 12,9 | 34,4 | 77,4 |
| | Cost Eff | EUR/t HF avoided | 1234 | 463 | 206 |
| Option 1 to 3 | Delta Cost | EUR/yr | 39.806 | 39.806 | 39.806 |
| | Delta HF | t HF/yr | 17,2 | 38,7 | 81,7 |
| | Cost Eff | EUR/t HF avoided | 2314 | 1029 | 487 |
| Option 2 to 3 | Delta Cost | EUR/yr | 23.884 | 23.884 | 23.884 |
| | Delta HF | t HF/yr | 4,3 | 4,3 | 4,3 |
| | Cost Eff | EUR/t HF avoided | 5554 | 5554 | 5554 |

## Comments

The first part of the table (option 1 to 2) illustrates the importance of the initial situation when assessing cost effectiveness. For the same end result (10 mg/m3) the cost per ton abated is much lower with high HF content in the inlet. Consequently, the need to install a stage 1 abatement system is justified - totally for 100 mg/m3, and probably also for 25 mg/m3.

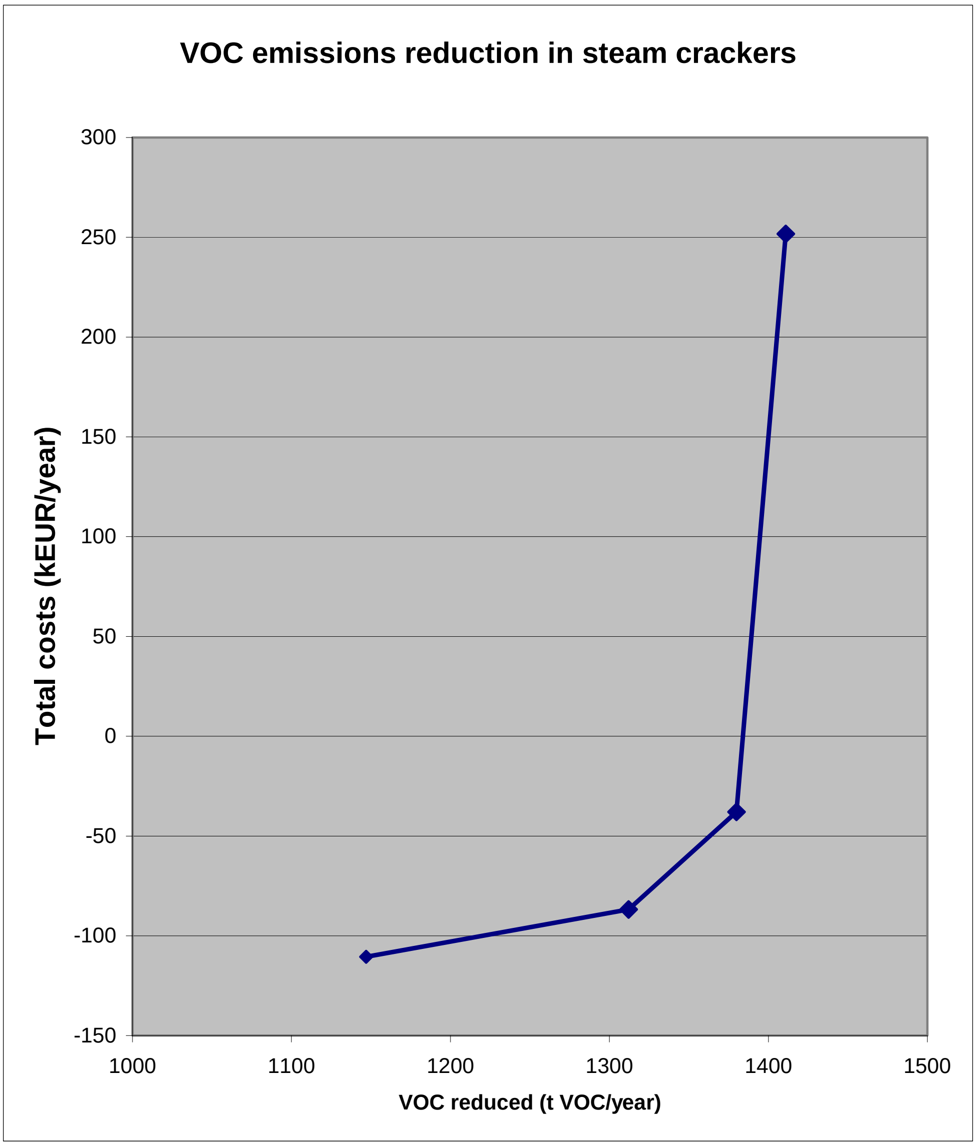
In the 3d part of the table (option 2 to 3) it is clear that the cost effectiveness is not affected by the HF inlet content at the entrance of stage 1. Consequently, a reduction from 10 mg/m3 to 5 mg/m3 seems disproportionate and should not be justified except in exceptional cases.

There is a temptation to consider independently the case “option 1 to 3”, especially in the case of 100 mg/m3 where the cost effectiveness of option 1 to 3 appears to be low (487 EUR/t). As explained before, the existence of option 2 excludes the installation of option 3 because of excessive differential costs (5554 EUR/t).

## 2. FUGITIVE EMISSIONS IN A STEAM CRACKER

Reference installation: steam cracker with a capacity of 480 kt ethylene and 270 kt propylene
Channeled emission (from stacks) can be considered to be recycled at a maximum level
The challenge concerns fugitive emissions. Industry considers Leak Detection And Repair systems with increased complexity and costs: P01 to P04 level of action.
Costs are a combination of investments, operational costs and positive income from the recovered VOC. In this exercise "VOC" are Non Methane VOC ("NMVOC") only.

| Reduction Measure | Total emissions ton VOC/year | Compared to the base case P00 | | | Comparison option n with option n-1 | | |
|---|---|---|---|---|---|---|---|
| | | Total cost EUR/year | VOC emission reduction ton VOC/year | Cost effectiveness EUR/ ton VOC reduced | Delta cost (EUR/year) | Delta VOC (t VOC/y) | Cost effectiveness EUR/ ton VOC reduced |
| P00 | 2550 | 0 | 0 | | | | |
| P01 | 1403 | -110564 | 1147 | -96 | -110564 | 1147 | -96 |
| P02 | 1238 | -86723 | 1312 | -66 | 23841 | 165 | 144 |
| P03 | 1170 | -37989 | 1380 | -28 | 48734 | 68 | 717 |
| P04 | 1139 | 251683 | 1411 | 178 | 289672 | 31 | 9344 |



**Comments**

When increasing the level of requirement of the LDAR, more and more VOC is recovered (i.e. emissions are reduced) but the costs increased dramatically and means that the net cost follows the same trend. The comparison of P01 to P04 versus P00 (the base case) leads to the feeling that P01 is obviously the minimum standard to require, that P02 to P03 are still “profitable” and consequently should also be options to consider seriously, and that only P04 could be the subject of a discussion.

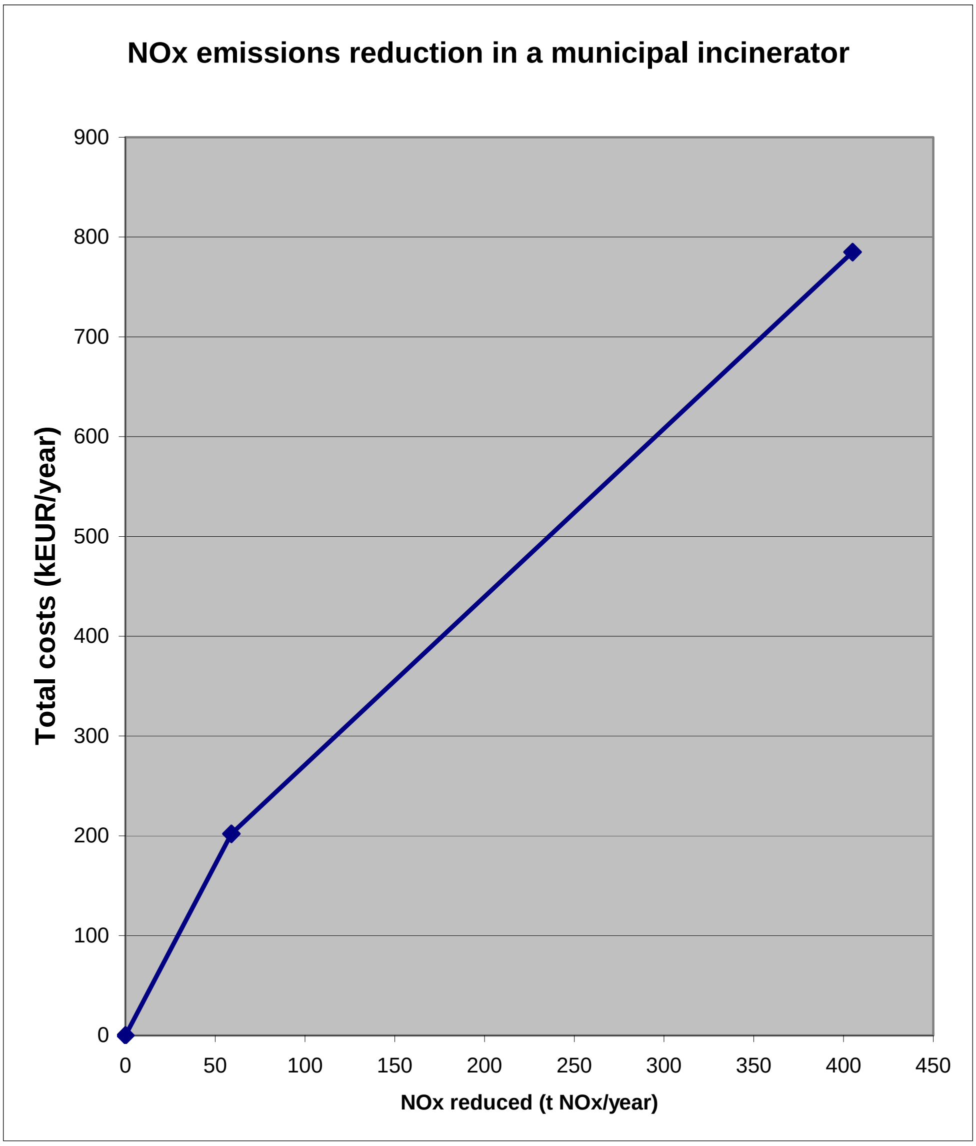
However, when considering the comparison between P(n) and P(n-1) there are other conclusions. If P01 stays an obvious minimum to require, the other cases are disputable: less and less emission reduction and more and more costs. The cost effectiveness on P02 versus P01 is 144 EUR/t VOC, the one for P03 versus P02 is 717 EUR/t VOC and the last P04 versus P03 is extremely high at 9344 EUR/t.

P04 seems not to be an option since no known references today, in external costs or shadow prices, are of this order of magnitude. The discussion will therefore be limited to the implementation of P01 only or P02 or P03 according to the reference cost used in the specific country or region.

## 3. NOx REDUCTION IN A MUNICIPAL WASTE INCINERATOR

Reference installation: fluidised bed municipal waste incinerator (capacity 100 kt waste/year)
The challenge concerns NOx emissions which are, without abatement systems, at 200 mg/Nm3
The problem is to analyse 2 possible options for reducing NOx emissions
Option 1: Base case - no abatement
Option 2: SNCR (with NH3 injection)
Option 3: SCR (with NH3 injection)

| Reduction Measure | Total emissions ton NOx/year | Compared to the base case Option1 | | | Comparison option n with option n-1 | | |
|---|---|---|---|---|---|---|---|
| | | Total cost EUR/year | NOx emission reduction ton NOx/year | Cost effectiveness EUR/ ton NOx reduced | Delta cost (EUR/year) | Delta NOx (t VOC/y) | Cost effectiveness EUR/ ton NOx reduced |
| Option 1 | 591 | 0 | 0 | | | | |
| Option 2 | 532 | 202000 | 59 | 3424 | 202000 | 59 | 3424 |
| Option 3 | 186 | 785000 | 405 | 1938 | 583000 | 346 | 1685 |



**Comments**

Taken individually, the cost effectiveness for option 2 is EUR 3424/tonne and EUR 1938/tonne for option 3. However, the marginal cost effectiveness of option 3 versus option 2 is lower than these two values, at 1685 EUR/tonne. This demonstrates that option 2 has a fundamental problem: the cost per tonne of NOx reduced for option 2 is higher than for option 3, despite the fact that it results in significantly lower emission reduction. Technically, it shows that ammonia injection is simply not effective considering the relatively low NOx level before treatment

On the graph it can be shown that the slope from option 1 to option 2 is higher than the slope from option 1 to option 3. This means that option 2 does not incrementally achieve sufficient reduction in emissions over option 1 to be justified, and that the evaluation must be limited to option 1 and option 3. In other words, the slope of the line [O1,O2] is higher than that of line [O2,O3], meaning that if option 2 is justified, option 3 is necessarily justified as well and option 2 is not a valid alternative. This illustrates the fact that an alternative must be compared with the next lower option in terms of avoided emissions (in this case, option 3 versus option 2) by evaluating the marginal difference in cost and in avoided emission between the two alternatives.