4 BEST AVAILABLE TECHNIQUES

4.1 Introduction

In understanding this chapter and its contents, the attention of the reader is drawn back to the preface of this document and in particular to the text quoted below:

From Section 3 of the Preface, 'Relevant legal obligations of the IPPC Directive and the definition of BAT':

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

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

The term 'best available techniques' is defined in Article 2(12) of the Directive.

Furthermore, Annex IV to the Directive contains a list of 'considerations to be taken into account generally or in specific cases when determining best available techniques bearing in mind the likely costs and benefits of a measure and the principles of precaution and prevention'. These considerations include the information published by the Commission to comply with Article 17(2).

Competent authorities responsible for issuing permits are required to take account of the general principles set out in Article 3 when determining the conditions of the permit. These conditions must include emission limit values, supplemented or replaced where appropriate by equivalent parameters or technical measures. According to Article 9(4) of the Directive:

(without prejudice to compliance with environmental quality standards), the emission limit values, equivalent parameters and technical measures shall be based on the best available techniques, without prescribing the use of any technique or specific technology, but taking into account the technical characteristics of the installation concerned, its geographical location and the local environmental conditions. In all circumstances, the conditions of the permit shall include provisions on the minimisation of long-distance or transboundary pollution and ensure a high level of protection for the environment as a whole.

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

From Section 6 of the Preface, 'How to understand and use this document':

The information provided in this document is intended to be used as an input to the determination of BAT for energy efficiency 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 including energy efficiency.

This chapter (Chapter 4) presents the techniques that are considered to be compatible with BAT in a general sense. The purpose is to provide general indications about energy efficiency techniques 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 does not propose energy efficiency values for permits. 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 judgements between different types of environmental impact, and these judgements will often be influenced by local considerations.

The best available techniques presented in this chapter will 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.

As a consequence of the integrated approach and the need to balance cross-media effects (as summarised above), energy efficiency ultimately should be considered for the installation as a whole, i.e.:

- it may not be possible to maximise the energy efficiencies of all activities and/or systems in the installation at the same time
- it may not be possible to both maximise the total energy efficiency and minimise other consumptions and emissions (e.g. it may not be possible to reduce emissions such as those to air without using energy)
- the energy efficiency of one or more systems may be de-optimised to achieve the overall maximum efficiency for an installation. See Sections 1.3.5 and 1.5.1.1
- it is necessary to keep the balance between maximising energy efficiency and other factors, such as product quality and the stability of the process
- the use of 'wasted' or surplus heat and/or renewable energy sources may be more sustainable than using primary fuels, even if the energy efficiency in use is lower.

Energy efficiency techniques are therefore proposed as 'optimising energy efficiency'.

The techniques presented in this chapter have been assessed through an iterative process involving the following steps:

- identification of the key energy efficiency issues within the scope of the IPPC Directive (see the Preface and Scope[32])
- examination of the techniques most relevant to address these key issues
- identification of the best energy efficiencies achievable, on the basis of the available data in the European Union and worldwide

[32] Energy efficiency in the IPPC Directive and the scope of this document, as well as the interface with other legislation and policy commitments is discussed in the Preface and Scope. It was concluded there that this document would not discuss such issues as the use of renewable energy sources.

- examination of the conditions under which these performance levels were achieved; such as costs, cross-media effects, and the main driving forces involved in implementing the techniques
- selection of the best available techniques (BAT) in a general sense according to Article 2(12) and Annex IV to the Directive.

Expert judgement by the European IPPC Bureau and the relevant Technical Working Group (TWG) has played a key role in each of these steps and in the way in which the information is presented here.

Where available, data concerning costs have been given together with the description of the techniques presented in the previous chapters. These give a rough indication about the magnitude of the costs involved. However, the actual cost of applying a technique will depend strongly on the specific situation regarding, for example, taxes, fees, and the technical characteristics of the installation concerned. It is not possible to evaluate such site-specific factors fully in this document. In the absence of data concerning costs, conclusions on economic viability of techniques are drawn from observations on existing installations.

It is intended that the general BAT in this chapter are a reference point against which to judge the current performance of an existing installation or to judge a proposal for a new installation. In this way they will assist in the determination of appropriate 'BAT-based' conditions for the installation or in the establishment of general binding rules under Article 9(8) of the IPPC Directive. It is foreseen that new installations can be designed to perform at or even better than the general BAT presented here. It is also considered that existing installations could move towards the general BAT or do better, subject to the technical and economic applicability of the techniques in each case.

While the BAT reference documents do not set legally binding standards, they are meant to give information for the guidance of industry, Member States and the public on achievable emission and consumption levels when using specified techniques (including energy efficiencies given in vertical sector BREFs), or the equivalent parameters and technical measures (Article 9(4)). The appropriate conditions for any specific case will need to be determined taking into account the objectives of the IPPC Directive and the local considerations.

<u>Identification of horizontal BAT</u>
The horizontal approach to energy efficiency in all IPPC sectors is based on the premise that energy is used in all installations, and that common systems and equipment occur in many IPPC sectors. Horizontal options for energy efficiency can therefore be identified independently of a specific activity. On this basis, BAT can be derived that embrace the most effective measures to achieve a high level of energy efficiency as a whole. Because this is a horizontal BREF, BAT need to be determined more broadly than for a vertical BREF, such as to consider the interaction of processes, units and systems within a site.

Process-specific BAT for energy efficiency and associated energy consumption levels are given in the appropriate ‘vertical’ sector BREFs. Some of these have been broadly summarised in [283, EIPPCB].

BAT for specific installations is, therefore, the combination of the specific BAT elements in the relevant sector BREFs, specific BAT for associated activities that may be found in other vertical BREFs, and the generic BAT elements presented in this chapter: those that are general to all installations can be found in Section 4.2 and the relevant BAT for certain systems, processes, activities or equipment are given in Section 4.3 (the relationship is shown in Figure 4.1).

Neither this chapter, nor Chapters 2 and 3 give exhaustive lists of techniques which may be considered, and therefore other techniques may exist or may be developed which may be equally valid within the framework of IPPC and BAT.

Implementation of BAT
The implementation of BAT in new or significantly upgraded plants or processes is not usually a problem. In most cases, it makes economic sense to optimise energy efficiency. Within an existing installation, the implementation of BAT is not generally so easy, because of the existing infrastructure and local circumstances: the economic and technical viability of upgrading these installations needs to be taken into account (see the Preface and the details listed below). The ECM REF [167, EIPPCB, 2006] refers to the following factors:

- for a new plant or major upgrade, the stage of commitment to a selection of techniques (i.e. the point at which changes in design can no longer be cost-effectively made)
- the age and design of the equipment
- the position of the installation in its investment cycle
- the complexity of processes and the actual selection of techniques used in the installation
- the production capacity, volumes and the mix of products being produced
- the type of treatments being applied and quality requirements
- the space available
- cost, 'availability' and robustness of techniques in the timescale required by the operator
- the time required to make changes to activities (including any structural changes) within the installation and how this is optimised with production requirements
- the cost-benefit of any ongoing environmental measures
- new and emerging techniques
- financial and cross-media costs.

Nevertheless, this document does not generally distinguish between new and existing installations. Such a distinction would not encourage the operators of industrial sites to move towards adopting BAT. There is generally a payback associated with energy efficiency measures and due to the high importance attached to energy efficiency, many policy implementation measures, including financial incentives, are available. Information on European and MS action plans and regulations can be found in Annex 7.13.

Some of the techniques are applied continuously and others are applied periodically, in whole or in part. For example, some maintenance tasks are carried out daily, while others are carried at appropriate times, e.g. servicing equipment at shut down times.

Some techniques are very desirable, and often implemented, but may require the availability and cooperation of a third party (e.g. cogeneration), which is not considered in the IPPC Directive.

Aids to understand this chapter
During the preparation of this document, it has become apparent that there is an order in which it is helpful to consider the application of techniques and therefore BAT. This is reflected in the order of the BAT sections, below, and in Figure 4.1.

The first priority is the selection and operation of core processes of the activities covered by the processes. These are discussed in their vertical sector BREFs, which are the first reference point.

In some cases, techniques which can be applied to associated activities in an installation are discussed in a separate vertical sector BREF, e.g. in the LCP, WI or WT BREFs.

However, energy efficiency is a cross-cutting issue, and there are aspects that are not dealt with in the vertical sector BREFs, or that need to be addressed uniformly across sectors. These are addressed in this document.

The first step is an action programme based on an Energy Efficiency Management System (ENEMS), referred to in Section 4.2.1. This may be dealt with (i) by an EMS referred to in the vertical sector BREF, (ii) such an EMS can be amended or (iii) the EMS can be supplemented by a separate ENEMS. Specific BAT apply when upgrading existing installations or developing new ones.

Sections 4.2.2 to 4.2.9 support the implementation of certain sections of the ENEMS. They contain BAT providing more detail on techniques.

Section 4.3 contains BAT for certain common systems, processes, associated activities or equipment which have an impact on the energy efficiency of the installation and are not discussed in detail in vertical BREFs. These may be identified during the course of assessing an installation.

In many cases, additional information is summarised from the discussions in earlier chapters, under the heading *'Applicability'*. This gives information such as which installations the BAT applies to, the frequency and complexity of applying the BAT, etc.

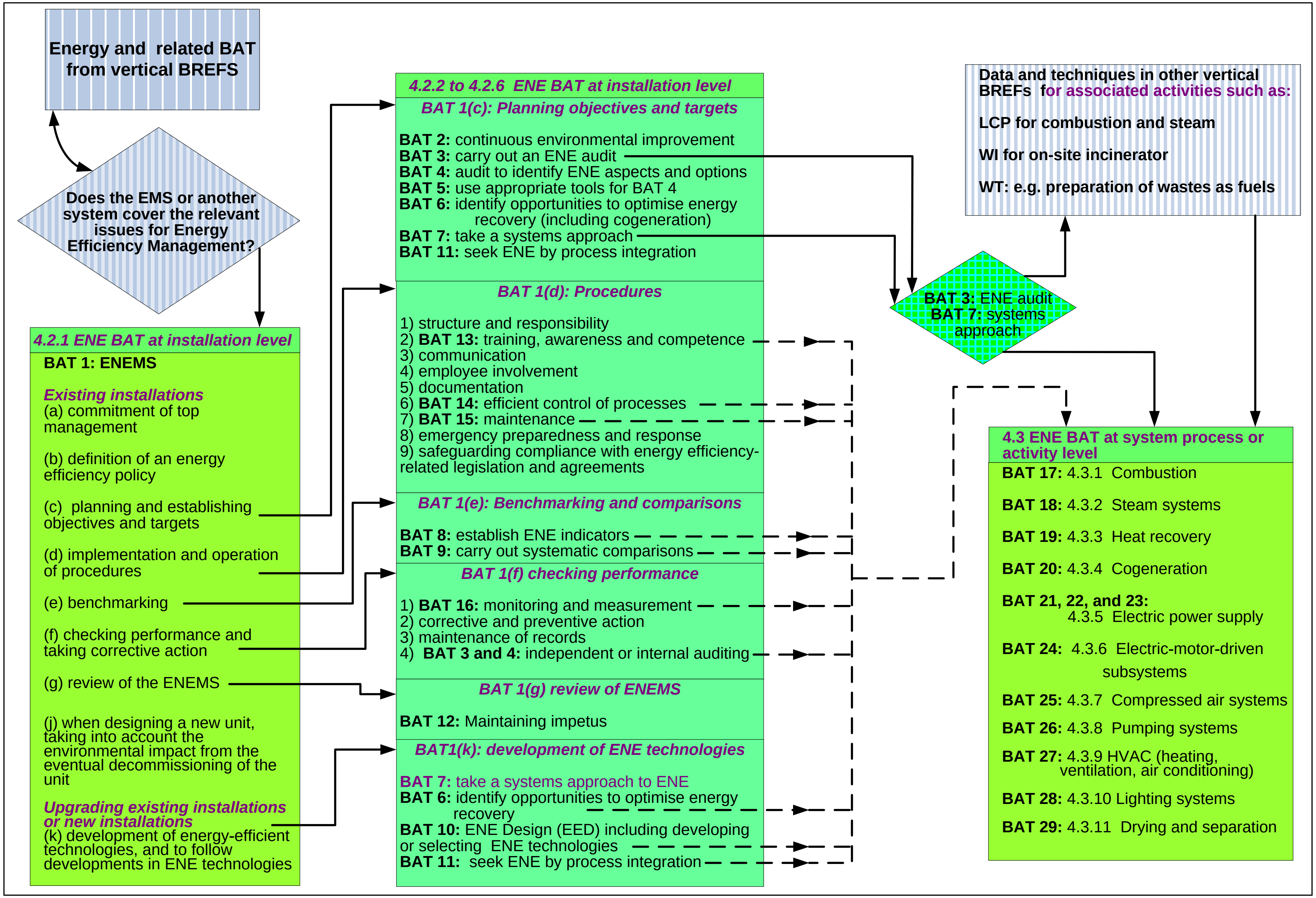

Figure 4.1: Relationships between BAT for Energy efficiency

4.2 Best available techniques for achieving energy efficiency at installation level

The key element to deliver energy efficiency at an installation level is a formal management approach, described in BAT 1. This is supported by the BAT in the following sections.

4.2.1 Energy efficiency management

A number of energy efficiency management techniques are determined as BAT. The scope (e.g. level of detail) and nature of the energy efficiency management system (ENEMS) (e.g. standardised or non-standardised) will generally be related to the nature, scale and complexity of the installation, as well as the energy requirements of the component processes and systems (see Section 2.1):

1. **BAT is to implement and adhere to an energy efficiency management system (ENEMS) that incorporates, as appropriate to the local circumstances, all of the following features (see Section 2.1.** The letters (a), (b), etc. below, correspond those in Section 2.1**):**

a. commitment of top management (commitment of the top management is regarded as a precondition for the successful application of energy efficiency management)

b. definition of an energy efficiency policy for the installation by top management

c. planning and establishing objectives and targets (see BAT 2, 3 and 8)

d. implementation and operation of procedures paying particular attention to:
   - i) structure and responsibility
   - ii) training, awareness and competence (see BAT 13)
   - iii) communication
   - iv) employee involvement
   - v) documentation
   - vi) effective control of processes (see BAT 14)
   - vii) maintenance (see BAT 15)
   - viii) emergency preparedness and response
   - ix) safeguarding compliance with energy efficiency-related legislation and agreements (where such agreements exist).

e. benchmarking: the identification and assessment of energy efficiency indicators over time (see BAT 8), and the systematic and regular comparisons with sector, national or regional benchmarks for energy efficiency, where verified data are available (see Sections 2.1(e), 2.16 and BAT 9)

f. checking performance and taking corrective action paying particular attention to:
   - i) monitoring and measurement (see BAT 16)
   - ii) corrective and preventive action
   - iii) maintenance of records
   - iv) independent (where practicable) internal auditing in order to determine whether or not the energy efficiency management system conforms to planned arrangements and has been properly implemented and maintained (see BAT 4 and 5)

g. review of the ENEMS and its continuing suitability, adequacy and effectiveness by top management

For (h) and (i), see further features on an energy efficiency statement and external verification, below

j. when designing a new unit, taking into account the environmental impact from the eventual decommissioning of the unit

k. development of energy-efficient technologies, and to follow developments in energy efficiency techniques.

The ENEMS may be achieved by ensuring these elements form part of existing management systems (such as an EMS) or by implementing a separate energy efficiency management system.

Three further features are considered as supporting measures. Although these features have advantages, systems without them can be BAT. These three additional steps are:

- (see Section 2.1(h)) preparation and publication (and possibly external validation) of a regular energy efficiency statement describing all the significant environmental aspects of the installation, allowing for year-by-year comparison against environmental objectives and targets as well as with sector benchmarks as appropriate
- (see Section 2.1(i)) having the management system and audit procedure examined and validated by an accredited certification body or an external ENEMS verifier
- (see Section 2.1, Applicability, 2) implementation and adherence to a nationally or internationally accepted voluntary system such as:
  - DS2403, IS 393, SS627750, VDI Richtlinie No. 46, etc.
  - (when including energy efficiency management in an EMS) EMAS and EN ISO 14001:1996. This voluntary step could give higher credibility to the ENEMS. However, non-standardised systems can be equally effective provided that they are properly designed and implemented.

Applicability: All installations. The scope and nature (e.g. level of detail) of applying this ENEMS will depend on the nature, scale and complexity of the installation, and the energy requirements of the component processes and systems.

4.2.2 Planning and establishing objectives and targets

4.2.2.1 Continuous environmental improvement

An important aspect of environmental management systems is continuing environmental improvement. This requires maintaining a balance for an installation between consumption of energy, raw materials and water, and the emissions (see Sections 1.1.6 and 2.2.1). Planned continuous improvement can also achieve the best cost-benefit for achieving energy savings (and other environmental benefits).

2. BAT is to continuously minimise the environmental impact of an installation by planning actions and investments on an integrated basis and for the short, medium and long term, considering the cost-benefits and cross-media effects.

Applicability: All installations.
'Continuously' means the actions are repeated over time, i.e. all planning and investment decisions should consider the overall long term aim to reduce the environmental impacts of the operation. This may mean avoiding short term actions to better use available investments over a longer term, e.g. changes to the core process may require more investment and take longer to implement, but may bring bigger reductions in energy use and emissions (see examples in Section 2.2.1).

The environmental benefits may not be linear, e.g. 2 % energy savings every year for 10 years. They may be stepwise, reflecting investment in ENE projects, etc. (see Section 2.2.1). Equally, there may be cross-media effects: for example it may be necessary to increase energy consumption to abate an air pollutant.

Environmental impacts can never be reduced to zero, and there will be points in time where there is little or no cost-benefit to further actions. However, over a longer period, with changing technology and costs (e.g. energy prices), the viability may also change.

4.2.2.2 Identification of energy efficiency aspects of an installation and opportunities for energy savings

In order to optimise energy efficiency, the aspects of an installation that influence energy efficiency need to be identified and quantified (see Section 2.11). Energy savings can then be identified, evaluated, prioritised and implemented according to BAT 2, above (see Section 2.1(c)).

3. BAT is to identify the aspects of an installation that influence energy efficiency by carrying out an audit. It is important that an audit is coherent with a systems approach (see BAT 7).

Applicability: All existing installations and prior to planning upgrades or rebuilds. An audit may be internal or external.

The scope of the audit and nature (e.g. level of detail, the time between audits) will depend on the nature, scale and complexity of the installation and the energy consumption of the component processes and systems (see Section 2.8.), e.g.:

- *in large installations with many systems and individual energy-using components such as motors, it will be necessary to prioritise data collection to necessary information and significant uses*
- *in smaller installations, a walk-through type audit may be sufficient.*

The first energy audit for an installation may be called an energy diagnosis.

4. When carrying out an audit, BAT is to ensure that the audit identifies the following aspects (see Section 2.11):

a. energy use and type in the installation and its component systems and processes

b. energy-using equipment, and the type and quantity of energy used in the installation

c. possibilities to minimise energy use, such as:
   - controlling/reducing operating times, e.g. switching off when not in use (e.g. see Sections 3.6, 3.7, 3.8, 3.9, 3.11)
   - ensuring insulation is optimised, e.g. see Sections 3.1.7, 3.2.11 and 3.11.3.7
   - optimising utilities, associated systems, processes and equipment (see Chapter 3)

d. possibilities to use alternative sources or use of energy that is more efficient, in particular energy surplus from other processes and/or systems, see Section 3.3

e. possibilities to apply energy surplus to other processes and/or systems, see Section 3.3

f. possibilities to upgrade heat quality (see Section 3.3.2).

Applicability: All installations. The scope of the audit and the nature (e.g. level of detail) will depend on the nature, scale and complexity of the installation, and the energy consumption of the component processes and systems.

Examples of some techniques for optimising systems and processes are given in the relevant sections in Chapter 3.

5. BAT is to use appropriate tools or methodologies to assist with identifying and quantifying energy optimisation, such as:

- energy models, databases and balances (see Section 2.15)
- a technique such as pinch methodology (see Section 2.12) exergy or enthalpy analysis (see Section 2.13), or thermoeconomics (see Section 2.14)
- estimates and calculations (see Sections 1.5 and 2.10.2).

Applicability: Applicable to every sector. The choice of appropriate tool or tools will depend on the sector, and the size, complexity and energy usage of the site. This will be site-specific, and is discussed in the relevant sections.

6. BAT is to identify opportunities to optimise energy recovery within the installation, between systems within the installation (see BAT 7) and/or with a third party (or parties), such as those described in Sections 3.2, 3.3 and 3.4.

Applicability: The scope for energy recovery depends on the existence of a suitable use for the heat at the type and quantity recovered (see Sections 3.3 and 3.4, and Annexes 7.10.2 and 7.10.3). A systems approach is set out in Section 2.2.2 and BAT 7). Opportunities may be identified at various times, such as a result of audits or other investigations, when considering upgrades or new plants, or when the local situation changes (such as a use for surplus heat is identified in a nearby activity).

The cooperation and agreement of a third party may not be within the control of the operator, and therefore may not be within the scope of an IPPC permit. In many cases, public authorities have facilitated such arrangements or are the third party.

4.2.2.3 A systems approach to energy management

The major energy efficiency gains are achieved by viewing the installation as a whole and assessing the needs and uses of the various systems, their associated energies and their interactions (see Sections 1.3.5, 1.4.2 and 2.2.2).

7. BAT is to optimise energy efficiency by taking a systems approach to energy management in the installation. Systems to be considered for optimising as a whole are, for example:

- process units (see sector BREFs)
- heating systems such as:
  - steam (see Section 3.2)
  - hot water
- cooling and vacuum (see the ICS BREF)
- motor driven systems such as:
  - compressed air (see Section 3.7)
  - pumping (see Section 3.8)
- lighting (see Section 3.10)
- drying, separation and concentration (see Section 3.11).

Applicability: All installations. The scope and nature (e.g. level of detail, frequency of optimisation, systems to be considered at any one time) of applying this technique will depend on factors such as the nature, scale and complexity of the installation, the energy requirements of the component processes and systems and the techniques considered for application.

4.2.2.4 Establishing and reviewing energy efficiency objectives and indicators

Quantifiable, recorded energy efficiency objectives are crucial for achieving and maintaining energy efficiency. Areas for improvement are identified from an audit (see BAT 3). Indicators need to be established to assess the effectiveness of energy efficiency measures. For process industries, these are preferably indicators related to production or service throughput (e.g. GJ/t product, see Section 1.3), termed specific energy consumption (SEC). Where a single energy objective (such as SEC) cannot be set, or where it is helpful, the efficiency of individual processes, units or systems may be assessed. Indicators for processes are often given in the relevant sector BREFS (for an overview, see [283, EIPPCB])

Production parameters (such as production rate, product type) vary and these may affect the measured energy efficiency and should be recorded to explain variations and to ensure that energy efficiency is realised by the techniques applied (see Sections 1.4 and 1.5). Energy use and transfers may be complicated and the boundary of the installation or system being assessed should be carefully defined on the basis of entire systems (see Sections 1.3.5 and 1.4.2 and BAT 7). Energy should be calculated on the basis of primary energy, or the energy uses shown as secondary energy for the different utilities (e.g. process heat as steam use in GJ/t, see Section 1.3.6.1).

8. BAT is to establish energy efficiency indicators by carrying out all of the following:

a. identifying suitable energy efficiency indicators for the installation, and where necessary, individual processes, systems and/or units, and measure their change over time or after the implementation of energy efficiency measures (see Sections 1.3 and 1.3.4)

b. identifying and recording appropriate boundaries associated with the indicators (see Sections 1.3.5 and 1.5.1)

c. identifying and recording factors that can cause variation in the energy efficiency of the relevant process, systems and/or units (see Sections 1.3.6 and 1.5.2).

Applicability: All installations. The scope and nature (e.g. level of detail) of applying these techniques will depend on the nature, scale and complexity of the installation, and the energy consumption of the component processes and systems.

Secondary or final energies are usually used for monitoring ongoing situations. In some cases, it may be most convenient to use more than one secondary or final energy indicator, for example, in the pulp and paper industry, where both electricity and steam are given as joint energy efficiency indicators. When deciding on the use (or change) of energy vectors and utilities, the energy indicator used may also be the secondary or final energy. However, other indicators such as primary energy or carbon balance may be used, to take account of the production of any secondary energy vector and the cross-media effects, depending on local circumstances (see Section 1.3.6.1).

4.2.2.5 Benchmarking

Benchmarking is a powerful tool for assessing the performance of a plant and the effectiveness of energy efficiency measures, as well as overcoming paradigm blindness[33]. Data may be found in sector BREFs, trade association information, national guidance documents, theoretical energy calculations for processes, etc. Data should be comparable and may need to be corrected, e.g. for type of feedstock. Data confidentiality may be important, such as where energy consumption is a significant part of the cost of production, although it may be possible to protect data (see Section 2.16). See also the establishment of energy indicators in BAT 8.

Benchmarking can also be applied to processes and working methods (see Sections 2.5 and 2.16).

9. BAT is to carry out systematic and regular comparisons with sector, national or regional benchmarks, where validated data are available.

Applicability: All installations. The level of detail will depend on the nature, scale and complexity of the installation, and the energy consumption of the component processes and systems. Confidentiality issues may need to be addressed (see Section 2.16): for instance, the results of benchmarking may remain confidential. Validated data include those in BREFs, or those verified by a third party. The period between benchmarkings is sector-specific and usually long (i.e. years), as benchmark data rarely change rapidly or significantly in a short time period.

4.2.3 Energy-efficient design (EED)

The planning phase of a new installation, unit or system (or one undergoing major refurbishment) offers the opportunity to consider the lifetime energy costs of processes, equipment and utility systems, and to select the most energy-efficient options, with the best lifetime costs (see Section 2.1(c)).

10. BAT is to optimise energy efficiency when planning a new installation, unit or system or a significant upgrade (see Section 2.3) by considering all of the following:

a. the energy-efficient design (EED) should be initiated at the early stages of the conceptual design/basic design phase, even though the planned investments may not be well-defined. The EED should also be taken into account in the tendering process

b. the development and/or selection of energy-efficient technologies (see Sections 2.1(k) and 2.3.1)

c. additional data collection may need to be carried out as part of the design project or separately to supplement existing data or fill gaps in knowledge

d. the EED work should be carried out by an energy expert

e. the initial mapping of energy consumption should also address which parties in the project organisations influence the future energy consumption, and should optimise the energy efficiency design of the future plant with them. For example, the staff in the (existing) installation who may be responsible for specifying design parameters.

[33] Paradigm blindness is a term used to describe the phenomenon that occurs when the dominant paradigm prevents one from seeing viable alternatives, i.e. 'the way we do it is best, because we've always done it this way'

Applicability: All new and significantly refurbished installations, major processes and systems. Where relevant in-house expertise on ENE is not available (e.g. non-energy intensive industries), external ENE expertise should be sought (see Section 2.3).

4.2.4 Increased process integration

There are additional benefits to seeking process integration, such as optimising raw material usage.

11. BAT is to seek to optimise the use of energy between more than one process or system (see Section 2.4), within the installation or with a third party.

Applicability: All installations. The scope and nature (e.g. level of detail) of applying this technique will depend on the nature, scale and complexity of the installation, and the energy requirements of the component processes and systems.

The cooperation and agreement of a third party may not be within the control of the operator, and therefore may not be within the scope of an IPPC permit. In many cases, public authorities have facilitated such arrangements or are the third party.

4.2.5 Maintaining the impetus of energy efficiency initiatives

To successfully achieve ongoing energy efficiency improvement over time, it is necessary to maintain the impetus of energy efficiency programmes (see Section 2.5).

12. BAT is to maintain the impetus of the energy efficiency programme by using a variety of techniques, such as:

a. implementing a specific energy efficiency management system (see Section 2.1 and BAT 1)

b. accounting for energy usage based on real (metered) values, which places both the obligation and credit for energy efficiency on the user/bill payer (see Sections 2.5, 2.10.3 and 2.15.2)

c. the creation of financial profit centres for energy efficiency (see Section 2.5)

d. benchmarking (see Section 2.16 and BAT 9)

e. a fresh look at existing management systems, such as using operational excellence (see Section 2.5)

f. using change management techniques (also a feature of operational excellence, see Section 2.5).

Applicability: All installations. It may be appropriate to use one technique or several techniques together. The scope and nature (e.g. level of detail) of applying these techniques will depend on the nature, scale and complexity of the installation, and the energy consumption of the component processes and systems. Techniques (a), (b) and (c) are applied and maintained according to the relevant sections referred to. The frequency of application of techniques such as (d), (e) and (f) should be far enough apart to enable the progress of the ENE programme to be assessed, and is therefore likely to be several years.

4.2.6 Maintaining expertise

Human resources are required for the implementation and control of energy efficiency management, and staff whose work may affect energy should receive training (see Section 2.1(d)(i) and (ii), and Section 2.6).

13. BAT is to maintain expertise in energy efficiency and energy-using systems by using techniques such as:

a. recruitment of skilled staff and/or training of staff. Training can be delivered by in-house staff, by external experts, by formal courses or by self-study/development (see Section 2.6)

b. taking staff off-line periodically to perform fixed term/specific investigations (in their original installation or in others, see Section 2.5)

c. sharing in-house resources between sites (see Section 2.5)

d. use of appropriately skilled consultants for fixed term investigations (e.g. see Section 2.11)

e. outsourcing specialist systems and/or functions (e.g. see Annex 7.12)

Applicability: All installations. The scope and nature (e.g. level of detail) of applying these techniques will depend on the nature, scale and complexity of the installation, and the energy requirements of the component processes and systems.

4.2.7 Effective control of processes

14. BAT is to ensure that the effective control of processes is implemented by techniques such as:

a. having systems in place to ensure that procedures are known, understood and complied with (see Sections 2.1(d)(vi) and 2.5)

b. ensuring that the key performance parameters are identified, optimised for energy efficiency and monitored (see Sections 2.8 and 2.10)

c. documenting or recording these parameters (see Sections 2.1(d)(vi), 2.5, 2.10 and 2.15).

Applicability: All installations. The scope and nature (e.g. level of detail) of applying these techniques will depend on the sector, nature, scale and complexity of the installation, and the energy requirements of the component processes and systems.

4.2.8 Maintenance

Structured maintenance and the repair of equipment that uses energy and/or controls energy use at the earliest opportunity are essential for achieving and maintaining efficiency (see Sections 2.1(d)(vii), 2.9 and BAT 1).

15. BAT is to carry out maintenance at installations to optimise energy efficiency by applying all of the following:

a. clearly allocating responsibility for the planning and execution of maintenance

b. establishing a structured programme for maintenance based on technical descriptions of the equipment, norms, etc. as well as any equipment failures and consequences. Some maintenance activities may be best scheduled for plant shutdown periods

c. supporting the maintenance programme by appropriate record keeping systems and diagnostic testing

d. identifying from routine maintenance, breakdowns and/or abnormalities possible losses in energy efficiency, or where energy efficiency could be improved

e. identifying leaks, broken equipment, worn bearings, etc. that affect or control energy usage, and rectifying them at the earliest opportunity.

Applicability: All installations. The scope and nature (e.g. level of detail) of applying these techniques will depend on the nature, scale and complexity of the installation, and the energy requirements of the component processes and systems. Carrying out repairs promptly has to be balanced (where applicable) with maintaining the product quality and process stability and the health and safety issues of carrying out repairs on the operating plant (e.g. it may contain moving and/or hot equipment, etc.).

4.2.9 Monitoring and measurement

Monitoring and measurement are an essential part of checking in a ‘plan-do-check-act’ system, such as in energy management (Section 2.1). It is also a part of the effective control of processes (see BAT 14).

16. BAT is to establish and maintain documented procedures to monitor and measure, on a regular basis, the key characteristics of operations and activities that can have a significant impact on energy efficiency. Some suitable techniques are given in Section 2.10.

Applicability: All installations. The scope and nature (e.g. level of detail) of applying this technique will depend on the nature, scale and complexity of the installation, and the energy requirements of the component processes and systems.

4.3 Best available techniques for achieving energy efficiency in energy-using systems, processes, activities or equipment

Introduction
Section 4.2.2.3 identifies the importance of seeing *the installation as a whole, and assessing the needs and purposes of the various systems, their associated energies and their interactions.* BAT 7 gives examples of systems commonly found in installations.

In Section 4.2, there are BAT that are generally applicable to all systems, processes and associated activities. These include:

- analysing and benchmarking the system and its performance (BAT 1, 3, 4, 8 and 9)
- planning actions and investments to optimise energy efficiency considering the cost-benefits and cross-media effects (BAT 2)
- for new systems, optimising energy efficiency in the design of the installation, unit or system and in the selection of processes (BAT 10)
- for existing systems, optimising the energy efficiency of the system through its operation and management, including regular monitoring and maintenance (see BAT 14, 15 and 16).

The BAT presented in this section therefore assume that these general BAT in Section 4.2 are also applied to the systems described below, as part of their optimisation.

4.3.1 Combustion

Combustion is a widely used process for both direct heating (such as in cement and lime manufacture, steel making) and indirect heating (such as firing steam boiler systems and electricity generation). Techniques for energy efficiency in combustion are therefore addressed in the appropriate sector BREFs. For other cases, such as combustion in associated activities, the Scope of the LCP BREF states:

'...smaller units can potentially be added to a plant to build one larger installation exceeding 50 MW. This means that all kinds of conventional power plants (e.g. utility boiler, combined heat and power plants, district heating plants.) used for mechanical power and heat generation are covered by this (LCP BREF) work.'

17. BAT is to optimise the energy efficiency of combustion by relevant techniques such as:

- those specific to sectors given in vertical BREFs
- those given in Table 4.1.

	Techniques for sectors and associated activities where combustion is not covered by a vertical BREF				
	Techniques in the LCP BREF July 2006 by fuel type and section				Techniques in this document (the ENE BREF) by section
	Coal and lignite	**Biomass and peat**	**Liquid fuels**	**Gaseous fuels**	
Lignite pre-drying	4.4.2				
Coal gasification	4.1.9.1 4.4.2 7.1.2				
Fuel drying		5.1.2, 5.4.2 5.4.4			
Biomass gasification		5.4.2 7.1.2			
Bark pressing		5.4.2 5.4.4			
Expansion turbine to recover the energy content of pressurised gases				7.1.1 7.1.2 7.4.1 7.5.1	
Cogeneration	4.5.5 6.1.8	5.3.3 5.5.4	4.5.5 6.1.8	7.1.6 7.5.2	3.4 Cogeneration
Advanced computerised control of combustion conditions for emission reduction and boiler performance	4.2.1 4.2.1.9 4.4.3 4.5.4	5.5.3	6.2.1 6.2.1.1 6.4.2 6.5.3.1	7.4.2 7.5.2	
Use of the heat content of the flue-gas for district heating	4.4.3				
Low excess air	4.4.3 4.4.6	5.4.7	6.4.2 6.4.5	7.4.3	3.1.3 Reducing the mass flow of the flue-gases by reducing the excess air

	Techniques for sectors and associated activities where combustion is not covered by a vertical BREF				
	Techniques in the LCP BREF July 2006 by fuel type and section				Techniques in this document (the ENE BREF) by section
	Coal and lignite	**Biomass and peat**	**Liquid fuels**	**Gaseous fuels**	
Lowering of exhaust gas temperatures	4.4.3		6.4.2		3.1.1 Reduction of the flue-gas temperature by: • dimensioning for the maximum performance plus a calculated safety factor for surcharges • increasing heat transfer to the process by increasing either the heat transfer rate, or increasing or improving the heat transfer surfaces • heat recovery by combining an additional process (for example, steam generation by using economisers,) to recover the waste heat in the flue-gases • installing an air or water preheater or preheating the fuel by exchanging heat with flue-gases (see 3.1.1 and 3.1.1.1). Note that the process can require air preheating when a high flame temperature is needed (glass, cement, etc.) • cleaning of heat transfer surfaces that are progressively covered by ashes or carbonaceous particulates, in order to maintain high heat transfer efficiency. Soot blowers operating periodically may keep the convection zones clean. Cleaning of the heat transfer surfaces in the combustion zone is generally made during inspection and maintenance shutdown, but online cleaning can be applied in some cases (e.g. refinery heaters)
Low CO concentration in the flue-gas	4.4.3		6.4.2		
Heat accumulation			6.4.2	7.4.2	
Cooling tower discharge	4.4.3		6.4.2		
Different techniques for the cooling system (see the ICS BREF)	4.4.3		6.4.2		

	Techniques for sectors and associated activities where combustion is not covered by a vertical BREF				
	Techniques in the LCP BREF July 2006 by fuel type and section				Techniques in this document (the ENE BREF) by section
	Coal and lignite	Biomass and peat	Liquid fuels	Gaseous fuels	
Preheating of fuel gas by using waste heat				7.4.2	3.1.1 Reduction of the flue-gas temperature: • preheating the fuel by exchanging heat with flue-gases (see 3.1.1). Note that the process can require air preheating when a high flame temperature is needed (glass, cement, etc.)
Preheating of combustion air				7.4.2	3.1.1 Reduction of the flue-gas temperature: • installing an air preheater by exchanging heat with flue-gases (see 3.1.1.1). Note that the process can require air preheating when a high flame temperature is needed (glass, cement, etc.)
Recuperative and regenerative burners					3.1.2
Burner regulation and control					3.1.4
Fuel choice					Note that the use of non-fossil fuels may be more sustainable, even if the ENE in use is lower
Oxy-firing (oxyfuel)					3.1.6
Reducing heat losses by insulation					3.1.7
Reducing losses through furnace doors					3.1.8
Fluidised bed combustion	4.1.4.2	5.2.3			

Table 4.1: Combustion system techniques to improve energy efficiency

4.3.2 Steam systems

Steam is a widely used heat transport medium because of its non-toxic nature, stability, low cost and high heat capacity, and flexibility in use. Steam utilisation efficiency is frequently neglected, as it is as not as easily measured as the thermal efficiency of a boiler. It may be determined using tools such as those in BAT 5 in conjunction with appropriate monitoring (see Section 2.10).

18. BAT for steam systems is to optimise the energy efficiency by using techniques such as:

- those specific to sectors given in vertical BREFs
- those given in Table 4.2

Techniques for sectors and associated activities where steam systems are not covered by a vertical BREF		
Techniques in the ENE BREF		
	Benefits	***Section in this document***
DESIGN		
Energy-efficient design and installation of steam distribution pipework	Optimises energy savings	2.3
Throttling devices and the use of backpressure turbines: utilise backpressure turbines instead of PRVs	Provides a more efficient method of reducing steam pressure for low-pressure services. Applicable when size and economics justify the use of a turbine	
OPERATING AND CONTROL		
Improve operating procedures and boiler controls	Optimises energy savings	3.2.4
Use sequential boiler controls (apply only to sites with more than one boiler)	Optimises energy savings	3.2.4
Install flue-gas isolation dampers (applicable only to sites with more than one boiler)	Optimises energy savings	3.2.4
GENERATION		
Preheat feed-water by using: • waste heat, e.g. from a process • economisers using combustion air • deaerated feed-water to heat condensate • condensing the steam used for stripping and heating the feed water to the deaerator via a heat exchanger	Recovers available heat from exhaust gases and transfers it back into the system by preheating feed-water	3.2.5 3.1.1
Prevention and removal of scale deposits on heat transfer surfaces. (Clean boiler heat transfer surfaces)	Promotes effective heat transfer from the combustion gases to the steam	3.2.6
Minimise boiler blowdown by improving water treatment. Install automatic total dissolved solids control	Reduces the amount of total dissolved solids in the boiler water, which allows less blowdown and therefore less energy loss	3.2.7
Add/restore boiler refractory	Reduces heat loss from the boiler and restores boiler efficiency	3.1.7 2.9
Optimise deaerator vent rate	Minimises avoidable loss of steam	3.2.8
Minimise boiler short cycling losses	Optimises energy savings	3.2.9
Carrying out boiler maintenance		2.9
DISTRIBUTION		
Optimise steam distribution systems (especially to cover the issues below)		2.9 and 3.2.10
Isolate steam from unused lines	Minimises avoidable loss of steam and reduces energy loss from piping and equipment surfaces	3.2.10
Insulation on steam pipes and condensate return pipes. (Ensure that steam system piping, valves, fittings and vessels are well insulated)	Reduces energy loss from piping and equipment surfaces	3.2.11 and 3.2.11.1
Implement a control and repair programme for steam traps	Reduces passage of live steam into the condensate system and promotes efficient operation of end-use heat transfer equipment. Minimises avoidable loss of steam	3.2.12
RECOVERY		

Techniques for sectors and associated activities where steam systems are not covered by a vertical BREF				
Collect and return condensate to the boiler for re-use. (Optimise condensate recovery)	Recovers the thermal energy in the condensate and reduces the amount of makeup water added to the system, saving energy and chemicals treatment			3.2.13
Re-use of flash-steam. (Use high-pressure condensate to make low-pressure steam)	Exploits the available energy in the returning condensate			3.2.14
Recover energy from boiler blowdown	Transfers the available energy in a blowdown stream back into the system, thereby reducing energy loss			3.2.15
Techniques in the LCP BREF July 2006 by fuel type and by section				
	Coal and lignite	***Biomass and peat***	***Liquid fuels***	***Gaseous fuels***
Expansion turbine to recover the energy content of pressurised gases				7.4.1 and 7.5.1
Change turbine blades	4.4.3	5.4.4	6.4.2	
Use advanced materials to reach high steam parameters	4.4.3		6.4.2	7.4.2
Supercritical steam parameters	4.4.3, 4.5.5		6.4.2	7.1.4
Double reheat	4.4.3, 4.5.5		6.4.2, 6.5.3.1	7.1.4, 7.4.2, 7.5.2
Regenerative feed-water	4.2.3, 4.4.3	5.4.4	6.4.2	7.4.2
Use of heat content of the flue-gas for district heating	4.4.3			
Heat accumulation			6.4.2	7.4.2
Advanced computerised control of the gas turbine and subsequent recovery boilers				7.4.2

Table 4.2: Steam system techniques to improve energy efficiency

4.3.3 Heat recovery

The main types of heat recovery systems are described in Section 3.3:

- heat exchangers (see Section 3.3.1)
- heat pumps (see Section 3.3.2).

Heat exchange systems are widely used with good results in many industrial sectors and systems, and are widely used for implementing BAT 5 and 11. Heat pumps are being increasingly used.

The use of 'wasted' or surplus heat may be more sustainable than using primary fuels, even if the energy efficiency in use is lower.

Heat recovery is not applicable where there is no demand that matches the production curve. However, it is being applied in an increasing number of cases, and many of these can be found outside of the installation, see Section 3.4 and Annex 7.10.

Techniques for cooling and the associated BAT are described in the ICS BREF, including techniques for the maintenance of heat exchangers.

19. BAT is to maintain the efficiency of heat exchangers by both:

a. monitoring the efficiency periodically, and

b. preventing or removing fouling

See Section 3.3.1.1.

4.3.4 Cogeneration

There is significant interest in cogeneration, supported at European Community level by the adoption of Directive 2004/8/EC on the promotion of cogeneration, and Directive 2003/96/EC on energy taxation, as well as by various national level policies and incentives. Relatively small scale plants may now be economically feasible, and incentives may also be available. In many cases, cogeneration has been successfully installed due to the assistance of local authorities. See Section 3.4 and Annex 7.10.3 and 7.10.4.

Utilities modelling, described in Section 2.15.2, can assist the optimisation of generation and heat recovery systems, as well as managing the selling and buying of surplus energy.

20. BAT is to seek possibilities for cogeneration, inside and/or outside the installation (with a third party).

Applicability: The cooperation and agreement of a third party may not be within the control of the operator, and therefore may not be within the scope of an IPPC permit.

Cogeneration is as likely to depend as much on economic conditions as ENE optimisation. Cogeneration opportunities should be sought on the identification of possibilities, on investment either on the generator's side or potential customer's side, identification of potential partners or by changes in economic circumstances (heat, fuel prices, etc.).

In general, cogeneration can be considered when:

- *the demands for heat and power are concurrent*
- *the heat demand (on-site and/or off-site), in terms of quantity (operating times during year), temperature, etc. can be met using heat from the CHP plant, and no significant heat demand reductions can be expected.*

Section 3.4 discusses the application of cogeneration, the different types of cogeneration (CHP) plants and their applicability in individual cases.

Successful implementation may depend on a suitable fuel and/or heat price in relation to the price of electricity. In many cases, public authorities (at local, regional or national level) have facilitated such arrangements or are the third party.

4.3.5 Electrical power supply

Quality of the electrical power supply and the manner in which the power is used can affect energy efficiency, see Section 3.5. This may be difficult to understand and is often overlooked. There are often energy losses as unproductive power inside the installation and in the external supply grid. There can also be loss of capacity in the installation's electrical distribution system, leading to voltage drops, causing overheating and premature failure of motors and other equipment. It may also lead to increased charges when buying in electricity.

21. **BAT is to increase the power factor according to the requirements of the local electricity distributor by using techniques such as those in Table 4.3, according to applicability (see Section 3.5.1).**

Technique	Applicability
Installing capacitors in the AC circuits to decrease the magnitude of reactive power	All cases. Low cost and long lasting, but requires skilled application
Minimising the operation of idling or lightly loaded motors	All cases
Avoiding the operation of equipment above its rated voltage	All cases
When replacing motors, using energy-efficient motors (see Section 3.6.1)	At time of replacement

Table 4.3: Electrical power factor correction techniques to improve energy efficiency

22. **BAT is to check the power supply for harmonics and apply filters if required (see Section 3.5.2).**

23. **BAT is to optimise the power supply efficiency by using techniques such as those in Table 4.4, according to applicability:**

Technique	Applicability	Section in this document
Ensure power cables have the correct dimensions for the power demand	When the equipment is not in use, e.g. at shutdown or when locating or relocating equipment	3.5.3
Keep online transformer(s) operating at a load above 40 – 50 % of the rated power	• for existing plants: when the present load factor is below 40 %, and there is more than one transformer • on replacement, use a low loss transformer and with a loading of 40 – 75 %	3.5.4
Use high-efficiency/low loss transformers	At time of replacement, or where there is a lifetime cost benefit	3.5.4
Place equipment with a high current demand as close as possible to the power source (e.g. transformer)	When locating or relocating equipment	3.5.4

Table 4.4: Electrical power supply techniques to improve energy efficiency

4.3.6 Electric-motor-driven subsystems[34]

Electric motors are widely used in industry. Replacement by electrically efficient motors (EEMs) and variable speed drives (VSDs) is one of the easiest measures when considering energy efficiency. However, this should be done in the context of considering the whole system the motor sits in, otherwise there are risks of:

- losing the potential benefits of optimising the use and size of the systems, and subsequently optimising the motor drive requirements
- losing energy if a VSD is applied in the wrong context.

[34] In this document 'system' is used to refer to a set of connected items or devices which operate together for a specific purpose, e.g. ventilation, CAS. See the discussion on system boundaries in Sections 1.3.5 and 1.5.1. These systems usually include motor sub-systems (or component systems).

The key systems using electric motors are:

- compressed air (CAS, see Section 3.7)
- pumping (see Section 3.8)
- heating, ventilation and air conditioning (see Section 3.9)
- cooling (see the ICS BREF).

24. BAT is to optimise electric motors in the following order (see Section 3.6):

1. optimise the entire system the motor(s) is part of (e.g. cooling system, see Section 1.5.1)
2. then optimise the motor(s) in the system according to the newly-determined load requirements, by applying one or more of the techniques in Table 4.5, according to applicability

Driven system energy savings measure	Applicability	Section in this document[1]
SYSTEM INSTALLATION or REFURBISHMENT		
Using energy-efficient motors (EEM)	Lifetime cost benefit	3.6.1
Proper motor sizing	Lifetime cost benefit	3.6.2
Installing variable speed drives (VSD)	Use of VSDs may be limited by security and safety requirements. According to load. Note in multi-machine systems with variable load systems (e.g. CAS) it may be optimal to use only one VSD motor	3.6.3
Installing high-efficiency transmission/reducers	Lifetime cost benefit	3.6.4
Use: • direct coupling where possible • synchronous belts or cogged V-belts in place of V belts • helical gears in place of worm gears	All	3.6.4
Energy-efficient motor repair (EEMR) or replacement with an EEM	At time of repair	3.6.5
Rewinding: avoid rewinding and replace with an EEM, or use a certified rewinding contractor (EEMR)	At time of repair	3.6.6
Power quality control	Lifetime cost benefit	3.5
SYSTEM OPERATION and MAINTENANCE		
Lubrication, adjustments, tuning	All cases	2.9
Note[1]: Cross-media effects, Applicability and Economics are given in Section 3.6.7		

Table 4.5: Electric motor techniques to improve energy efficiency

3. when the energy-using systems have been optimised, then optimise the remaining (non-optimised) motors according to Table 4.5 and criteria such as:

   i. prioritising the remaining motors running more than 2000 hrs per year for replacement with EEMs
   ii. electric motors driving a variable load operating at less than 50 % of capacity more than 20 % of their operating time, and operating for more than 2000 hours a year should be considered for equipping with variable speed drives.

4.3.7 Compressed air systems (CAS)

Compressed air is widely used as either part of a process or to provide mechanical energy. It is widely used where there is risk of explosion, ignition, etc. In many cases, it is used as an integral part of the process (such as providing low quality nitrogen as an inert atmosphere, and for blowing, moulding or mixing), and it is difficult to assess its mechanical efficiency. In some cases, e.g. where driving small turbines such as assembly tools, it has a low overall efficiency, and where there are no health and safety constraints, replacement with other drives may be considered (see Section 3.7).

25. BAT is to optimise compressed air systems (CAS) using the techniques such as those in Table 4.6, according to applicability:

Technique	Applicability	Section in this document
SYSTEM DESIGN, INSTALLATION or REFURBISHMENT		
Overall system design, including multi-pressure systems	New or significant upgrade	3.7.1
Upgrade compressor	New or significant upgrade	3.7.1
Improve cooling, drying and filtering	This does not include more frequent filter replacement (see below)	3.7.1
Reduce frictional pressure losses (for example by increasing pipe diameter)	New or significant upgrade	3.7.1
Improvement of drives (high-efficiency motors)	Most cost effective in small (<10 kW) systems	3.7.2, 3.7.3, 3.6.4
Improvement of drives (speed control)	Applicable to variable load systems. In multi-machine installations, only one machine should be fitted with a variable speed drive	3.7.2
Use of sophisticated control systems		3.7.4
Recover waste heat for use in other functions	Note that the gain is in terms of energy, not of electricity consumption, since electricity is converted to useful heat	3.7.5
Use external cool air as intake	Where access exists	3.7.8
Storage of compressed air near highly-fluctuating uses	All cases	3.7.10
SYSTEM OPERATION and MAINTENANCE		
Optimise certain end use devices	All cases	3.7.1
Reduce air leaks	All cases. Largest potential gain	3.7.6
More frequent filter replacement	Review in all cases	3.7.7
Optimise working pressure	All cases	3.7.9

Table 4.6: Compressed air system techniques to improve energy efficiency

4.3.8 Pumping systems

Some 30 to 50 % of the energy consumed by pumping systems may be saved through equipment or control system changes (see Section 3.8).

For electric motors used for driving pumps, see BAT 24. However, the use of VSDs (a key technique) is also mentioned in Table 4.7.

26. BAT is to optimise pumping systems by using the techniques in Table 4.7, according to applicability (see Section 3.8):

Technique	Applicability	Section in this document	Additional information
DESIGN			
Avoid oversizing when selecting pumps and replace oversized pumps	For new pumps: all cases For existing pumps: lifetime cost benefit	3.8.1 3.8.2	Largest single source of pump energy wastage
Match the correct choice of pump to the correct motor for the duty	For new pumps: all cases For existing pumps: lifetime cost benefit	3.8.2 3.8.6	
Design of pipework system (see Distribution system, below)		3.8.3	
CONTROL and MAINTENANCE			
Control and regulation system	All cases	3.8.5	
Shut down unnecessary pumps	All cases	3.8.5	
Use of variable speed drives (VSDs)	Lifetime cost benefit. Not applicable where flows are constant	3.8.5	See BAT 24, in Section 4.3.6
Use of multiple pumps (staged cut in)	When the pumping flow is less than half the maximum single capacity	3.8.5	
Regular maintenance. Where unplanned maintenance becomes excessive, check for: • cavitation • wear • wrong type of pump	All cases. Repair or replace as necessary	3.8.4	
DISTRIBUTION SYSTEM			
Minimise the number of valves and bends commensurate with keeping ease of operation and maintenance	All cases at design and installation (including changes). May need qualified technical advice	3.8.3	
Avoiding using too many bends (especially tight bends)	All cases at design and installation (including changes). May need qualified technical advice	3.8.3	
Ensuring the pipework diameter is not too small (correct pipework diameter)	All cases at design and installation (including changes). May need qualified technical advice	3.8.3	

Table 4.7: Pumping system techniques to improve energy efficiency

Note that throttle control wastes less energy than bypass control or no control. However, all are wasteful of energy and should be considered for replacement according to size of the pump and how frequently it is used.

4.3.9 Heating, ventilation and air conditioning (HVAC) systems

A typical HVAC system comprises the equipment providing some or all of the following functions:

- system heating (boilers, see Section 3.2; heat pumps, see Section 3.3.2, etc.)
- cooling (see Section 3.3)
- pumps (see Section 3.8)
- heat exchangers (see Section 3.3.1) transferring or absorbing heat from a space or a process
- space heating and cooling (Section 3.9.1)
- ventilation by fans extracting or providing air through ducts, to or from heat exchangers and/or the external air (see Section 3.9.2).

Studies have shown that about 60 % of the energy in an HVAC system is consumed by the chiller/heat pump and the remaining 40 % by peripheral machinery. Air conditioning is increasingly used across Europe, particularly in the south.

Ventilation is essential for many industrial installations to function. It:

- protects staff from pollutant and heat emissions within premises
- maintains a clean working atmosphere to protect product quality.

Requirements may be dictated by health, safety and process considerations (see Section 3.9).

27. BAT is to optimise heating, ventilation and air conditioning systems by using techniques such as:

- for ventilation, space heating and cooling, techniques in Table 4.8 according to applicability
- for heating, see Sections 3.2 and 3.3.1, and BAT 18 and 19
- for pumping, see Section 3.8 and BAT 26
- for cooling, chilling and heat exchangers, see the ICS BREF, as well as Section 3.3 and BAT 19 (in this document).

Energy savings measure	Applicability	Section in this document
DESIGN and CONTROL		
Overall system design. Identify and equip areas separately for: • general ventilation • specific ventilation • process ventilation	New or significant upgrade. Consider for retrofit on lifetime cost benefit	3.9.1 3.9.2.1
Optimise the number, shape and size of intakes	New or upgrade	3.9.2.1
Use fans: • of high efficiency • designed to operate at optimal rate	Cost effective in all cases	3.9.2.1 3.9.2.2
Manage airflow, including considering dual flow ventilation	New or significant upgrade	3.9.2.1
Air system design: • ducts are of a sufficient size • circular ducts • avoid long runs and obstacles such as bends, narrow sections	New or significant upgrade	3.9.2.1
Optimise electric motors, and consider installing a VSD	All cases. Cost effective retrofit	3.9.2.1, 3.9.2.2, 3.6, 3.6.3, 3.6.7 and BAT 24
Use automatic control systems. Integrate with centralised technical management systems	All new and significant upgrades. Cost effective and easy upgrade in all cases	3.9.2.1 3.9.2.2
Integration of air filters into air duct system and heat recovery from exhaust air (heat exchangers)	New or significant upgrade. Consider for retrofit on lifetime cost benefit. The following issues need to be taken into account: the thermal efficiency, the pressure loss, and the need for regular cleaning	3.9.2.1 3.9.2.2
Reduce heating/cooling needs by: • building insulation • efficient glazing • air infiltration reduction • automatic closure of doors • destratification • lowering of temperature set point during non-production period (programmable regulation) • reduction of the set point for heating and raising it for cooling	Consider in all cases and implement according to cost benefit	3.9.1
Improve the efficiency of heating systems through: • recovery or use of wasted heat (Section 3.3.1) • heat pumps • radiative and local heating systems coupled with reduced temperature set points in the non occupied areas of the buildings	Consider in all cases and implement according to cost benefit	3.9.1
Improve the efficiency of cooling systems through the use of free cooling	Applicable in specific circumstances	3.9.3
MAINTENANCE		
Stop or reduce ventilation where possible	All cases	3.9.2.2
Ensure system is airtight, check joints	All cases	3.9.2.2
Check system is balanced	All cases	3.9.2.2
Manage airflow: optimise	All cases	3.9.2.2
Air filtering, optimise: • recycling efficiency • pressure loss • regular filter cleaning/replacement • regular cleaning of system	All cases	3.9.2.2

Table 4.8: Heating, ventilation and air conditioning system techniques to improve energy efficiency

4.3.10 Lighting

Health and safety at work is the priority criterion for lighting systems requirements. The energy of lighting systems can be optimised according to the specific use requirements, see Section 3.10.

28. BAT is to optimise artificial lighting systems by using the techniques such as those in Table 4.9 according to applicability (see Section 3.10):

Technique	Applicability
ANALYSIS and DESIGN OF LIGHTING REQUIREMENTS	
Identify illumination requirements in terms of both intensity and spectral content required for the intended task	All cases
Plan space and activities in order to optimise the use of natural light	Where this can be achieved by normal operational or maintenance rearrangements, consider in all cases. If structural changes, e.g. building work, is required, new or upgraded installations
Selection of fixtures and lamps according to specific requirements for the intended use	Cost benefit on lifetime basis
OPERATION, CONTROL, and MAINTENANCE	
Use of lighting management control systems including occupancy sensors, timers, etc.	All cases
Train building occupants to utilise lighting equipment in the most efficient manner	All cases

Table 4.9: Lighting system techniques to improve energy efficiency

4.3.11 Drying, separation and concentration processes

The separation of (usually) a solid from a liquid may be carried out by one or more stages. By optimising the process steps necessary to achieve the required product, substantial energy savings can be achieved. Energy efficiency may be optimised by using two or more techniques in combination (see Section 3.11).

29. BAT is to optimise drying, separation and concentration processes by using techniques such as those in Table 4.10 according to applicability, and to seek opportunities to use mechanical separation in conjunction with thermal processes:

Technique	Applicability	Additional information	Section in this document
		DESIGN	
Select the optimum separation technology or combination of techniques (below) to meet the specific process equipments	All cases		3.11.1
		OPERATION	
Use of surplus heat from other processes	Depends on the availability of surplus heat in the installation (or from third party)	Drying is a good use for surplus heat	3.11.1
Use a combination of techniques	Consider in all cases	May have production benefits, e.g. improved product quality, increased throughput	3.11.1
Mechanical processes, e.g. filtration, membrane filtration	Process dependent. To achieve high dryness at lowest energy consumption, consider these in combination with other techniques	Energy consumption can be several orders of magnitude lower, but will not achieve high % dryness	3.11.2
Thermal processes, e.g. • directly heated dryers • indirectly heated dryers • multiple effect	Widely used, but efficiency can be improved by considering other options in this table	Convective (direct) heat dryers may be the option with the lowest energy efficiency	3.11.3 3.11.3.1 3.11.3.2 3.11.3.3 3.11.3.6
Direct drying	See thermal and radiant techniques, and superheated steam	Convective (direct) heat dryers may be the option with the lowest energy efficiency	3.11.3.2
Superheated steam	Any direct dryers can be retrofitted with superheated steam. High cost, needs lifetime cost benefit assessment. High temperature may damage product	Heat can be recovered from this process	3.11.3.4
Heat recovery (including MVR and heat pumps)	Consider for almost any continuous hot air convective dryers		3.11.1 3.11.3.5 3.11.3.6
Optimise insulation of the drying system	Consider for all systems. Can be retrofitted		3.11.3.7
Radiation processes e.g. • infrared (IR) • high frequency (HF) • microwave (MW)	Can be easily retrofitted. Direct application of energy to component to be dried. They are compact and Reduce the need for air extraction. IR limited by substrate dimensions. High cost, needs lifetime cost benefit assessment	More efficient heating. Can boost production throughput coupled with convection or conduction	3.11.4
		CONTROL	
Process automation in thermal drying processes	All cases	Savings of between 5 and 10 % can be achieved compared with using traditional empirical controllers	3.11.5

Table 4.10: Drying, separation and concentration system techniques to improve energy efficiency