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The BREF in the pulp and paper industry

BAT for an industry with a large variety of raw materials and products

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1 Introduction

The final draft BREF on Pulp and paper Industry has been available since February 2000. The document was generally endorsed by Member States and Industry at the IEF Meeting on 28/29 February 2000. Within the next weeks the consultation for the endorsement procedure will be completed so that an adopted version can be expected soon.

The reference document cannot be discussed here in detail because of its pure size and complexity. It comprises nearly 500 pages and contains detailed information on most environmental aspects of the sector. This presentation briefly highlights some characteristics of the sector, explains how the document presents best available techniques (BAT) for this complex industry with different raw materials and a wide variety of products, and discusses examples for the determination of BAT concerning emissions to water. It summarizes briefly major points of debate and how they were resolved in the Technical Working Group (TWG).

2 Some characteristics of the sector

The European Pulp and paper Industry is characterised by a large variety of raw materials, products and manufacturing routes. It was therefore one of the tasks of the TWG to find an appropriate approach to this industry that takes into account the complexity of the sector and the differences between pulp and paper mills.

2.1 Variety of products

In developed societies the use of a multitude of paper and board products is everyday reality for most people. A look at the main functional uses of paper and board shows the diversity of products. Paper is used for collection, distribution and storing of information, for packaging of goods, for hygienic purposes (personal care, cleanliness, disease prevention) and a large variety of special applications. In order to meet the customers needs the paper industry manufactures different products such as newsprint, printing and writing papers, magazine paper, packaging paper, boxes, tissue (toilet paper, kitchen towels, napkins, etc.) and a large number of special papers (e.g. stamps, air filters, coffee filters, baking paper etc.). Each of these categories demands specific properties of the product and the most appropriate manufacturing route to these products may differ substantially.

2.2 Variety of raw materials and processes

Paper is essentially a sheet of cellulose fibres with a number of added constituents to affect the quality of the sheet and its fitness for intended end use. Besides fibres and chemicals, manufacturing of pulp and paper requires a large amount of process water and energy in the form of steam and electric power.

The *pulp* for paper making may be produced from virgin fibre (wood) by chemical or mechanical means or may be produced by the re-pulping of recovered paper. In the pulping process the raw cellulose-bearing material is broken down into its individual fibres. In Europe, wood is the main raw material for virgin pulp production. In *chemical pulping*, chemicals are used to dissolve the lignin and free the fibres. The lignin, and many other organic substances, are thus put into solution from which the chemicals and the energy content of the lignin and other organics may be recovered. In mechanical pulping processes mechanical shear forces are used to pull the fibres apart and the majority of the lignin remains with the fibres although there is still dissolution of some organics. Pulps produced in different ways have different properties which make them suited to particular products.

Recovered paper has become an indispensable raw material for the paper manufacturing industry. Paper produced by the use of recovered paper as fibre source will involve some cleaning of contaminants prior to use and may involve de-inking depending upon the quality of material recycled and the requirements for the properties of the end product. Many different *recovered paper processing* systems are applied in European paper mills.

Paper may also comprise up to 45% of its weight in fillers, coatings and other substances.

Both the variety of raw materials used and the various end products result in a lot of different options for the manufacturing routes. However, the different raw materials used and processes involved can be broken down in a number of unit operations („building blocks„) that are similar in all mills (see section 3.1).

2.3 Variety of size of paper mills

According to item 6.1 of Annex I of the IPPC Directive industrial plants for the production of pulp from timber or other fibrous materials and paper and board with a production capacity exceeding 20 tonnes per day are supposed to be dealt with in the BREF. This definition of the scope includes all pulp mills and according to the Confederation of European Paper Industries (CEPI) 98% of the European paper mills. Consequently, the BREF addresses the whole industry and not only the biggest companies. This includes small paper mills e.g. in France, Germany, Italy, Portugal, Spain or U.K. producing around 10000 tonnes of paper per year. On the other side of the spectrum there are big paper mills that manufacture more than 250000 t/a.

3 BAT for pulp and paper mills

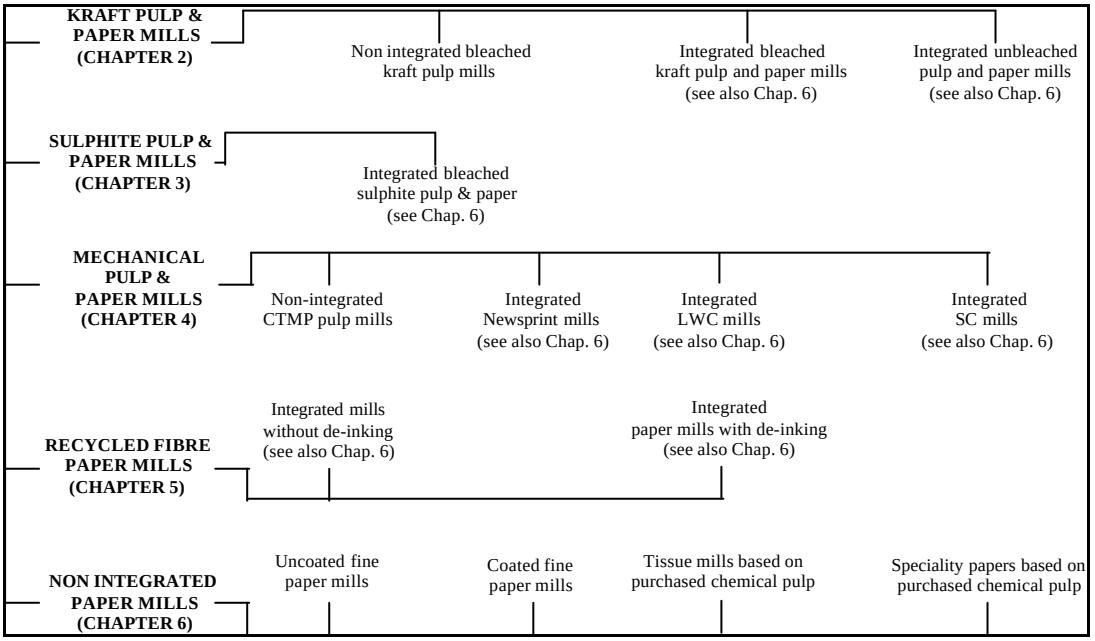
3.1 General structure of the BREF for the pulp and paper industry

At the beginning of the work on the BREF, a generally agreed structure of the sector had to be developed that separates the sector into different classes of mills from an environmental perspective. This was not an easy task because of the variety of raw

materials and products already mentioned above. However, it was indispensable because the use of different furnishes, the application of specific manufacturing routes and the manufacturing of specific product qualities result in different emissions and consequently different options for pollution prevention and control have to be considered.

Bearing in mind that there is no single right or wrong proposal and that there is no classification that covers all real cases a compromise was essential. The preferred proposal focuses on the common ground and then questions what separates the different groups. It is considered to be simple and manageable and gives preference to classifying the European Paper Industry according to major sources of pollution and possible techniques for pollution prevention and control. The proposed structure of the European pulp and paper industry as used in the BREF is shown in figure 1.

Figure 1: Classification of pulp and paper mills proposed by the BREF and structure of the document [1]



The BREF describes the most important pulp, paper and board manufacturing processes separately for five main classes. The main types of pulp and paper manufacturing are sub-divided in several sub-classes, where appropriate. From what has been said above - there is no classification that perfectly covers all real cases - it is obvious that the structure has to be fine-tuned to the structure of Paper Industry within the single Member States so that it fits to the specific characteristics and situation of the given industry.

3.2 Presentation of BAT

Manufacturing of pulp and paper is not a single process but a series of unit processes, often linked and interdependent. Consequently, several BATs for different

mill classes are necessary to address all products and processes involved in the European pulp and paper industry. For describing best available techniques for this sector the following aspects should be kept in mind:

- There is no single reference of best available techniques in pulp and paper industry. The list of best available techniques consists of many process-integrated and some external measures for prevention and control of pollution that constitute the overall BAT for pulp and paper mills. These components may be combined in different ways. BAT is therefore always a suitable combination of techniques. Following the integrated approach it is evident that BAT levels can be achieved in different ways, i.e. there are several options to achieve similar emission and consumption levels. When it comes to BAT associated emission levels, it is important to note that between mills the degree of application of techniques varies and consequently so do the associated emission levels.
- The BAT-concept includes a process-related element because the environmental impact may vary when processes with different pollution potential are applied (e.g. recovered paper processing to produce cartonboard can be carried out with or without de-inking). Besides product-related aspects (see next bullet), the applied processes determine the unabated emission of a mill. That means when approaching the pulp and paper industry different types of processes involved have to be taken into account.
- On the other hand, for the pulp and paper industry the best available techniques cannot be defined solely by describing unit processes. Instead, the whole installations must be examined and dealt with as entities. In this connection, the raw materials used and the product properties to be achieved are important influences to be taken into account. As a consequence, the process-oriented approach has to be extended by a product-oriented concept i.e. the BAT approach must be linked to the environmental performance of specific types of mills where specific products are manufactured. Thus, in this document best available techniques are presented for major mill classes separately (see section 3.1).
- Instead of single distinctive values the environmental performance of paper mills is expressed as a range of values reflecting that the manufacturing of different paper grades requires different quantities and qualities of raw materials (e.g. softwood/hardwood, different qualities of waste paper, mixture of furnishes etc.), with the consequence that emissions per end product may vary within a certain range. To a certain extent, higher emissions caused by the use of more polluting raw materials or processes respectively can be compensated by higher efforts for pollution prevention and control. Presenting ranges considers also that emissions vary with time to a certain extent, e.g. between years, even if the same techniques have been used.

3.3 Examples for the determination of BAT concerning emissions to water

The concept of IPPC - and thus of the BREF - covers several issues such as minimisation of resource and energy consumption, controlling emissions into air, water and soil, taking into account cross media effects and economics issues. Special emphasis is given to the IPPC principle of eliminating pollution by intervention at source by process integrated BAT measures. However, in order to achieve the general target of the Directive - a high level of protection for the environment as a whole - process integrated measures and end-of pipe techniques together constitute the overall BAT for pulp and paper mills.

Historically, pulp and paper mills were, and mostly still are located close to some body of water as the availability of water plays a major role in the production process. Rivers were used to generate the power needed for the pulping, to supply process water and as recipient for discharges from the mills. However, in the European paper Industry the discharges to water have been substantially reduced by means of a number of process integrated and external measures. There is a development to further closing up the water circuits in pulp and paper mills so that a further reduction of discharges can be expected in the future (towards effluent free mills). But to date, water is still one of the major raw materials in pulp and paper manufacturing. Pulp and paper mills are often a significant contributor of pollutant discharges to the environment.

So, some simplified examples with regard to water consumption and related discharges are chosen in order to explain how BAT is addressed in the BREF for this sector. It will be shown how the manufacturing of different raw materials and the production of different end products have an effect on the emission to water and how these aspects have been taken into account when deriving emissions levels that are associated with the use of BAT. The first example refers to the kraft pulp processing that uses wood as major raw material. The second example refers to recovered paper processing mills that use recycled material as fibre source. Because of limited space the description focuses on emissions to water and within this subject on the sum of discharged organic substances usually measured as chemical oxygen demand (COD). More details can be found in the BREF itself.

3.3.1 Example 1: Emissions to water from bleached kraft pulp mills

Kraft pulp mills are characterised by the fact that they have concentrated their environmental efforts on process-integrated measures. This trend is reflected in the BREF. BAT for bleached kraft pulp production is in the first place a combination of 11 internal measures shown in the two boxes below:

- Dry debarking of wood
- Modified cooking
- Closed cycle brown stock screening
- Highly efficient brown stock washing
- ECF or TCF final bleaching
- Some, mainly alkaline, process water recycling from the bleach plant
- Purification and re-use of the condensates

- Effective spill monitoring, containment, and recovery system
- Sufficient black liquor evaporation plant and recovery boiler to cope with the additional liquor and dry solids loads due to collection of spills, bleach plant effluents etc.
- Collection and re-use of clean cooling water
- Primary treatment of waste water

The efficiency of each of these measures varies considerably with the design and operation practices at different mills. To be regarded as BAT, a measure must also be well designed and operated. Depending on the type of pulp wood used, the specific process-integrated measures implemented and the technical characteristics of the mill, specific emission levels to water are associated with the use of a combination of BAT. In order to ensure transparency, the BREF gives BAT ranges before and after biological treatment. In doing so, the reader is in a position to easier follow how the BAT conclusions flow from the selected techniques and the assumptions made. The BREF therefore presents both the environmental performance of process integrated measures only, as well as the combination with external treatment.

In our example of bleached kraft pulp mills, the BAT range *before* biological treatment is:

- 30 - 45 kg COD per tonne of pulp produced

Biological waste water treatment is further regarded as BAT. A reduction efficiency of biological treatment of > 55 % for COD is considered BAT (up to 65-75% are achieved in well designed and controlled low loaded activated sludge plants with long retention times).

That gives a calculated BAT range *after* biological treatment of:

- 13.5 - 21 kg COD per tonne of pulp (or 8 - 12 with best achievements).

The BREF finally gives a BAT range of 8 - 23 kg COD per tonne of pulp. This emission level is achieved when a combination of together 12 measures is applied.

For better understanding of the BAT emission ranges some additional background information might be useful:

The BAT emission ranges in the BREF are always based on a number of real world examples that have achieved this level. In our example, there are 3 bleached kraft pulp mills that achieve around 8 kg COD per tonne of pulp (Canada, Finland, Sweden). These mills are the very best performers and confirm the lower end of the

range. Normally, for recently build mills or for those mills, which have increased substantially their production capacity it is somewhat easier to perform at the lower end of the BAT range presented in the BREF. On the other hand, the ranges are set wide enough to be applicable to most existing mills. This is confirmed by a larger number of other real world examples that fall within the whole BAT range. The upper end of the range considers also different starting points of mills and includes a balancing of cross media effects and cost aspects on a sector level. Those mills not achieving within the range associated with this general BAT could normally improve their performance towards the range. Under a European perspective - and also compared to the competitors in North America and Asia - the whole BAT emission range for kraft pulp mills stands for well performing mills. The very best performers could be expected to lie within the better part of the range whereas other mills achieving within the range may have implemented a set of BAT measures but not necessarily all and not necessarily to their full extent. The influence of different raw materials (softwood/ hardwood) and different product qualities (market pulp, pulp for integrated paper production) is also taken into account when proposing these ranges.

For some users of the BREF the range of emissions associated with BAT might seem to be quite wide. This is reflecting that for technical and economic reasons the majority of the TWG did not support more narrow ranges, which are closer to the very best achievements. The given BAT emission ranges are a result of balancing all the different views and technical and economic arguments exchanged in the TWG. They are not representing the best of the best. Nevertheless, they are reflecting a high level of protection of the environment as a whole.

3.3.2 Example 2: Emissions to water from recovered paper processing paper mills (RCF) without de-inking

Recovered paper processing systems vary mainly according to the paper grade to be produced e.g. packaging paper, newsprint, testliner, or tissue paper. Generally, recovered paper processes can be divided in two main categories:

- processes with exclusively mechanical cleaning i.e. *without de-inking*. They comprise products like case making materials, board and cartonboard;
- processes with mechanical and chemical unit processes i.e. *with de-inking*. They comprise products like newsprint, printing and copy paper, tissue, magazine papers (SC/LWC), some grades of cartonboard or market DIP.

The following example refers to the first group of mills, i.e. RCF paper mills without de-inking.

Again, BAT is a combination of internal measures and biological treatment. The following box gives an overview about BAT for reducing emissions to water:

- Separation of less contaminated water from contaminated one and recycling of process water;
- Optimal water management (water loop arrangement; water clarification by sedimentation, flotation or filtration techniques and recycling of process water for different purposes;
- Strict separation of water loops and counter-currents flow of process water;
- Installation of an equalisation basin and primary treatment;
- Biological effluent treatment;
- Partial recycling of treated water after biological treatment;
- Treating internal water circuits

It has to be noted that European RCF paper mills use different qualities of waste paper for the production of comparable products. Depending on the type of waste paper used and the specific process-integrated measures implemented, a pollution load before biological treatment of 20 - 40 kg COD per tonne of paper can be expected for RCF paper mills without de-inking. A waste water flow < 7 m³ per tonne of paper is considered BAT.

Concerning water consumption the TWG discussed whether or not the reduction of water use is an environmental benefit to be considered at sector level or whether it is only a concern for those areas where water is scarce. For pulp and paper mills it could be shown that the reduction of discharges is strongly related to the recovery and recycling of process water resulting in a reduction of fresh water consumption. Increased closure of water circuits in paper mills will result in less volume and more concentrated waste water, which in general can be treated more efficiently. Decrease of process water flows will also increase the applicability of internal measures and advanced technologies. Therefore, reduction of the intake of fresh water mostly leads to decreasing discharges to surface waters.

As already mentioned, biological waste water treatment is one of the BATs. Combined anaerobic-aerobic biological treatment is the preferable option for non-de-inked grades. This is because these mills usually have realised a high degree of water circuit closure resulting in very concentrated waste water that is favourable for anaerobic treatment. A reduction efficiency of > 95 - 97% for COD is considered BAT. That gives a calculated remaining COD load after biological treatment of 1 - 2 (with 95% reduction) and 0.6 - 1.2 kg/t (with 97% reduction). The BREF gives a BAT range of 0.5 - 1.5 kg COD per tonne of paper. This range reflects the different influences on the overall environmental performance of RCF paper mills (different raw materials i.e. waste paper of less or better quality; different products manufactured in different product lines at one mill such as e.g. testliner, wellenstoff, white topliner etc.)

RCF paper mills that produce paper from better quality waste paper i.e. that are faced with lower initial COD loads and that manufacture mostly bulk grades with less changes of paper grades can normally achieve the lower end of the range. Other

mills with more changes of grades, higher product qualities and worse waste paper quality (i.e. higher initial COD loads) might rather achieve the upper end of the range.

Again, the range is derived iteratively from a number of real world examples. There are a few mills that achieve 0.5 kg COD/t or even operate with zero liquid effluents. Concerning closed water systems however, the TWG Members did not support the option to consider this technique as BAT on a sector level because the few existing mills that have implemented closed water loops with in-line biological treatment of process water still have some operational problems to resolve. For instance, the uncontrolled precipitation of calcium carbonate in closed circuits applications is still waiting for a satisfactory technical solution. Although not yet generally applicable, closed water loops might be considered as a feasible option in specific cases. On the other hand, many RCF paper mills that have implemented the above mentioned BATs fall within the whole BAT range. As it stands now in the BREF, the emission levels that are associated with the use of BAT can be achieved by most mills independently from the quality of the waste paper used.

4 How major points of debate were resolved

The Best Available Techniques Reference Document in Pulp and paper Industry has met great support from the TWG and IEF. Generally, a high degree of consensus has been reached within the TWG. Nevertheless, in the course of the information exchange on BAT there were some points of debate that were discussed contentiously. The two major points of debate are briefly summarised below.

4.1 New and existing mills

A few Member States and CEPI expressed their view that the BAT associated emission levels should be presented separately for new and existing mills. What seems to be logical on the first view is more problematic from a practical point of view. Difficulties are caused by the fact that in pulp and paper mills, the applicability of a technique is not only driven by the fact whether a mill is new or existing. Pulp and paper mills are characterised by the trend that machinery is rebuilt over years rather than replaced whole-scale (modular rebuilding and development of plants). Thus, due to progressive rebuilding, updating, process control and environmental management systems, there are many existing mills with comparable or even better environmental performance (at least for some parameters) than recently built mills. Furthermore, BAT statements for new mills are to a certain extent speculation. Consequently, all descriptions and data of this document are based on existing mills.

4.2 Smaller and bigger mills

Another point of disagreement is that a few Member States and CEPI wished to have different BATs and BAT associated emission levels for smaller and bigger mills. The

difficulty in the Technical Working Group was that the experts provided no information on which techniques are in-applicable to smaller mills from a technical and economic point-of-view. Well-founded information on appropriate BAT levels for smaller mills have not been provided either and it is thus unclear which yardstick to use for this purpose. For some parameters the achievable environmental performance of smaller and bigger mills may vary within a certain range. On the other hand, there are also some smaller mills that achieve good environmental performance. Generally, the relevant techniques that are currently available for prevention or reduction of emissions and consumption are the same independent of the size of the mills. The impact, if any, of the size of the mill will be taken into account by the permitting authority in the Member State in question when determining BAT in the specific case. Therefore, no distinction of BAT between smaller and bigger mills should and has been made in the BREF. Generally, it can be stated that the specific costs for smaller mills are relatively higher (economies of scale), smaller mills might have less financial possibilities for technical changes, and it might happen that material or lay-out of older equipment does not suit to a higher degree of water closure. Smaller mills might sometimes not have the knowledge available which would be necessary to run and control more complex process solutions most efficiently.

5 Conclusions

The BREF for the Pulp and Paper Industry represents the information exchange on BAT that has taken place over the last three years. Special emphasis is given to the measures for prevention and controlling pollution by intervention at source by process integrated BAT measures. However, in order to achieve the general target of the Directive - a high level of protection for the environment as a whole - process integrated measures and end-of pipe techniques together constitute the overall BAT for pulp and paper mills.

The EIPPCB has assessed all information (whether provided by the TWG or collected itself) and has considered thoroughly all points of view from TWG Members. The document reflects, at a sector level, the variety of raw materials, products and processes in the European Paper Industry. The BREF is the product of a considerable breadth of expertise. It contains relevant information for decision-makers. The document meets broad support of the TWG. However, there are still a few points of disagreement. These points of debate are discussed within the Conclusion and Recommendation Chapter of the BREF.

6 References

[1] European Commission, Joint Research Centre, IPTS, European IPPC Bureau, Michael Suhr 2000. Draft Reference Document on Best Available Techniques in the Pulp and Paper Industry, Draft dated February 2000. The BREF Pulp and Paper Industry has been posted in pdf format on the web site of the European

IPPC Bureau (EIPPCB) http://eippcb.jrc.es (Activities - Pulp and Paper Industry - Documents) and can be downloaded. The pdf format is readable if one has the Adobe Acrobat reader software.

The BREF in the Pulp and Paper Industry.

BAT for an industry with a large variety of raw materials and products

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Overview

1. Characteristics of the sector
2. General structure of the BREF
3. Presentation of BAT
4. How to conclude on BAT ?
5. Major points of debate
6. Conclusions

1. Characteristics of the sector

- **Variety of products**
  - **chemical pulp, mechanical pulp; pulp from recovered paper processing**
  - **newsprint, printing & writing paper**
  - **packaging paper, boxes**
  - **tissue**
  - **special papers**

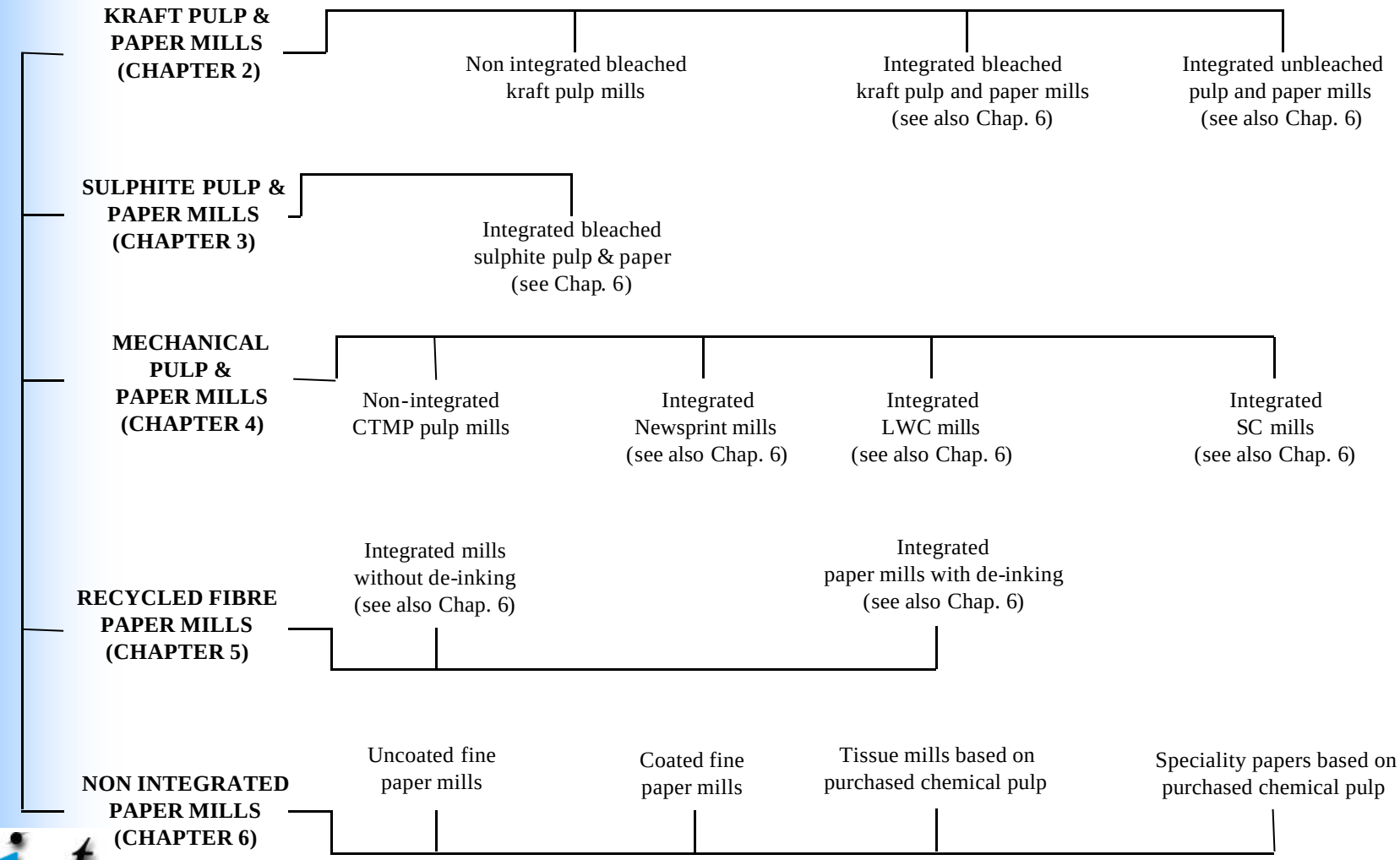
1. Characteristics of the sector

- **Variety of raw materials and processes**
  - **wood - main raw material for virgin pulp**
    - **chemical pulping**
      - kraft pulp
      - sulphite pulp
    - **mechanical pulping**
  - **Recovered paper - an indispensable fibre source**
    - **recovered paper processing**
      - with and without de-inking

1. Characteristics of the sector

- **Variety of size of pulp and paper mills**
  - **small paper mills producing around 10000 t/a as e.g. in France, Germany, Italy, Portugal and Spain**
  - **big paper mills that manufacture more than 250000 t/a (all countries)**
- **The industry is highly diverse and complex**
- **No classification perfectly covers all cases**

2. General structure of the BREF



3. Presentation of BAT

- ✓ **There is no single BAT**
- ✓ **BAT is a suitable combination of techniques**
- ✓ **Major mills presented separately with individual BAT**
- ✓ **Range of consumption and emission levels**
  - different raw materials and processes
  - different product qualities
- ✓ **Part compensation of higher emissions**
- ✓ **Assessment of BAT through an iterative process**

4. How to conclude on BAT ?

- **Example 1: Bleached kraft pulp mills**
  - **10 process integrated measures such e.g.**
    - **dry debarking of wood**
    - **modified cooking**
    - **closed cycle brown stock screening**
    - **highly efficient washing of the pulp**
    - **ECF or TCF final bleaching**
    - **some process water recycling from the bleach plant**
    - **etc.**
  - **Primary and biological waste water treatment**

4. How to conclude on BAT ?

- **Efficiency of these measures varies with the design and operation practices**
- **For transparency reasons emissions levels associated with BAT are given before and after treatment separately**

- before treatment: 30 - 45 kg COD/tonne of pulp

BAT is > 55% COD removal efficieny (e.g. activated sludge)

- after treatment: 8 - 23 kg COD/tonne of pulp

4. How to conclude on BAT ?

- **Example 2: Recovered paper processing mills without de-inking**
  - **Separation of less contaminated from more highly contaminated water and subsequent water recycling**
  - **Strict seperation of water loops and counter-current flow of process water**
  - **Optimal water loop arrangement and water clarification**
  - **Primary and biological waste water treatment**
  - **Partial recycling of treated water after biological treatm.**
  - **Treatment of internal water circuits**

4. How to conclude on BAT ?

- **different qualities of recovered paper is used as raw material**

⇨ **initial pollution load varies to a certain extent**

- **Again, emissions levels associated with BAT are given <u>before</u> and <u>after</u> treatment separately**

- before treatment: 20 - 40 kg COD/tonne of paper

BAT is > 95 - 97% COD removal efficieny (e.g. combined anaerobic/aerobic treatment)

- after treatment: 0.5 - 1.5 kg COD/tonne of paper

5. Major points of debate

- **Different consumption/emission levels associated with BAT for new and existing mills (the ranges should be wider)**
- **Different consumption/emission levels associated with BAT for smaller and bigger mills**
- **The BREF should better take account of the interrelation between the different measures**
  - **no evidence has been put forward to support the view that there is a technical reason why it would be imposible for a mill to meet all BAT levels**
  - **there are mills that already meet all BAT levels**

5. Some answers (new/existing mills)

- **Issue common to all sectors (Annex IV): take into account the length of time needed to introduce BAT**
- **P & P Industry is characterised by the fact that machinery is rebuilt over years rather than replaced whole-scale (modular rebuilding of plants)**
- **There are many existing mills with comparable or even better (at least for some media) than recently built mills**

5. Some answers (new/existing mills)

- **BAT statements for new mills are to a certain extent speculation**
- **All descriptions and data of this document are based on existing mills**
- **Normally, for recently built mills it is technically easier and relatively less expensive to perform at the lower end of the BAT range presented in the BREF**
- **The BAT ranges are wide enough to be applicable for existing mills**

5. Some answers (smaller/bigger mills)

- **Insufficient information was provided which techniques are not applicable for smaller mills**
- **Well-founded information on appropriate BAT levels were not provided either**
- **It is unclear which yardstick to use**
- **There are also smaller mills that achieve the BAT levels**
- **The impact, if any, of the size of the mill will be taken into account by the permitting authority**

6. Conclusions

- **The BREF represents the information exchange that has taken place**
- **is a product of a considerable breadth of expertise**
- **meets generally broad support of the TWG**
- **The remaining few points of disagreement are discussed in the Conclusion and Recommendation Chapter of the BREF**
- **The BREF reflects at a sector level the variety of raw materials, products and processes**

6. Conclusions

- **BAT is presented separately for major mill classes**
- **special emphasis is given to process-integrated measures**
- **process-integrated measures and end-of-pipe techniques together constitute the overall BAT for pulp and paper mills**
- **the emission levels associated with BAT are confirmed by a bigger number of real world examples**