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ENVIRONMENTAL IMPACT MINIMIZATION
IN PULP AND PAPER INDUSTRY

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ÖZET

KAĞIT HAMURU VE KAĞIT ENDÜSTRİSİNDE ÇEVRESEL ETKİ AZALTILMASI

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Kağıt hamuru ve kağıt endüstrisi dünyada ve ülkemizde hızla gelişmektedir ve bu endüstri önemli ölçüde doğal kaynak, hammadde ve enerji kullanmaktadır. Bu nedenle bu sektörün olumsuz çevresel etkilerini en aza indirmek önemlidir.

Bu çalışmada kağıt hamuru ve kağıt endüstrisinin çevresel konularda analiz edilmesi ve çevresel etkilerin azaltılması konusunda öneriler getirilmesi amaçlanmıştır.

Çalışmada kağıt hamuru ve kağıt endüstrisi ile ilgili temel bilgiler verilmiş ve mevcut temiz üretim teknolojileri örneklendirilmiştir. Ayrıca Avrupa Birliği Entegre Kirlilik Önleme ve Kontrolü (IPPC) Direktifi'nin sektör üzerindeki etkileri tartışılmıştır.

Kağıt ve kağıt hamuru üretimindeki proses adımları incelenmiş ve özellikle atık oluşumu üzerinde yoğunlaşmıştır. Sürdürülebilir kalkınma kavramı ve bazı çevre yönetim enstrümanları hakkında bilgi sağlanmış ve temiz üretim fikri sektörden bir çok örnek ile çalışılmıştır. AB IPPC Direktifi'nin sektörün Avrupa ve Türkiye'deki işletmelerin rekabet gücüne etkisi ve bazı çevre yönetim enstrümanları ile ilişkileri tartışılmıştır.

Anahtar sözcükler: Kağıt hamuru ve kağıt endüstrisi, temiz üretim, IPPC Direktifi

ABSTRACT**ENVIRONMENTAL IMPACT MINIMIZATION
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Pulp and paper industry is growing globally and this industry consumes a significant amount of natural sources, raw materials and energy. Due to this fact, minimizing the negative environmental impact of this sector is important.

The aim of this study is to analyze pulp and paper industry in environmental aspects and to develop options for minimizing the environmental impact of the industry.

Within this study, brief information about pulp and paper industry is given and possible cleaner production options in the sector are introduced. In addition to that, implications of European Union Integrated Pollution Prevention and Control Directive (IPPC) on pulp and paper industry are discussed.

During this study, process steps of pulp and paper manufacturing were investigated with giving special emphasis on waste generation. Issues of sustainable development and environmental management instruments were studied and cleaner production concept was investigated in details with examples from pulp and paper industry. The EU IPPC directive and reference document on pulp and paper industry was studied briefly. Effects of IPPC directive on the competitiveness power of the sector in Europe and in Turkey were determined, and possible interaction of the directive with other environmental management instruments was discussed.

Keywords: Pulp and paper industry, cleaner production, IPPC Directive

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NOMENCLATURE

Abbreviations	Definition
AOX	Adsorbable Organic Halogen
BAT	Best Available Techniques
BOD	Biological Oxygen Demand
BREF	BAT Reference Document
COD	Chemical Oxygen Demand
CP	Cleaner Production
ECF	Elemental Chlorine Free
EEA	European Economic Area
EL	Environmental Labeling
EMA	Environmental Management Accounting
EMS	Environmental Management Systems
EU	European Union
EUEB	European Eco-labeling Board
EUR	Euro
GNP	Gross National Product
HEN	Heat Exchanger Network Design
IPPC	Integrated Pollution Prevention And Control
LCA	Life Cycle Analysis

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NOMENCLATURE (Continued)

Abbreviations	Definition
MEN	Mass Exchange Network Design
RCF	Recycled Fiber
R&D	Research and Development
TCF	Total Chlorine Free
TRS	Total Reduced Sulfur
TSS	Total Suspended Solids
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
US	United States
WRI	World Resources Institute

1. INTRODUCTION

In every part of the day, different types of paper are used for different purposes. The significance of paper and paper products in modern life is obvious to everyone; no other manufactured product plays a more meaningful role in every area of human activity. The uses and applications for paper and paper products are limitless. Paper provides the means of recording, storage and dissemination of information; virtually all writing and printing is done on paper. It is the most widely used wrapping and packaging material, and is important for structural applications and hygienic purposes. New specialty products are continually being developed. At the same time, the industry is aware of the competition from other sectors; notably plastics and electronic media. As never before, new technology and methodology is being adopted so that the industry can remain competitive in existing markets and be receptive to new opportunities (Smook, 2002). In developed societies the use of a multitude of paper and board-based products is everyday reality for most people and per capita paper consumption always considered to be an indicator of the level of country's development. Leading paper producer countries in the world are tabulated in Table 1.1 (WRI, 2004) and Table 1.2 summarizes per capita paper consumption in selected countries where world average is 52.25 kilograms (WRI, 2004).

Table 1.1 Annual paper production figures (tones)

USA	83,611,789	Canada	20,578,000
China	37,929,000	Germany	20,392,000
Japan	30,457,000	Finland	14,036,000

Table 1.2 Per capita paper consumption (kg/year)

Australia	185.53	Greece	76.16	Romania	25.61
Austria	244.64	Indonesia	24.22	Russia	34.5
Brazil	45.01	Iran	9.86	South Africa	41.7
Canada	277.38	Italy	195.35	Sweden	222.67
China	33.62	Japan	249.64	Tunisia	18.66
Finland	333.96	Morocco	11.11	Turkey	34.46
France	182.78	Netherlands	226.72	UK	208.44
Germany	235.24	Nigeria	1.55	USA	312.08

In the last two decades, there is a growing consensus about the need to reduce the environmental impact of human activities. Two years after the 1992 Earth Summit was held in Rio de Janeiro, 166 nations had signed the treaty and the Earth Summit stood as a warning about the most critical issue of our time, the environment. Since 1950, the population of the world has grown from 2.5 billion people to over 5.6 billion; a fifth of the topsoil that makes it possible for us to grow the crops that we eat and feed to our domestic animals has been lost; a third to a half of all forests has been cut over; the characteristics of the atmosphere have changed drastically resulting in increases in the carbon dioxide and other greenhouse gases inexorably leading to global warming. Over the next three decades, up to 3 billion more people will be added to the world population, the grater majority of them in cities of the third world. Most of these people are likely to be condemned to a life of poverty and reduced expectations, as they cut over the remaining forests and exhaust the depleted soils of their native lands (Raven et al., 1995).

For all of these reasons, it is necessary for us to take effective steps to counteract the global problems that we confront. In dealing with them, we will find new solutions to our own problems, and help to secure our own future. Environmental concerns are getting more and more advanced. In the 1960s, waste treatment was considered only after the plant had been constructed; in the 1980s, waste treatment had gained consideration before the construction of the plant; in 2000s, the incorporation into the R&D (Research and Development) phase is achieved where all materials (from feedstock, catalysts, solvents to products) are required to be “green”. The earlier the stage is, the more the opportunities of environmental impact minimization are, and the lower the cost for modification is (Yang and Shi, 2000). Following Figure 1.1 situates the opportunities and associated costs for the environmental impact minimization opportunities along the process life cycle.

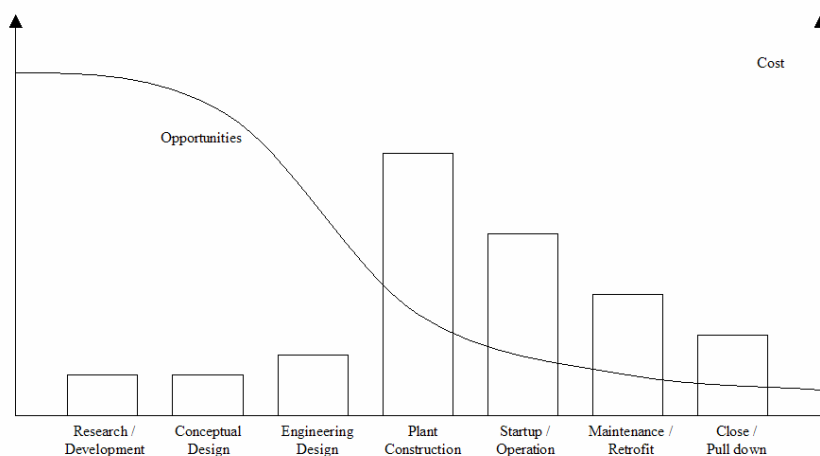


Figure 1.1 Opportunities for the environmental impact minimization along the process life cycle (Yang and Shi, 2000).

The pulp and paper industry is growing globally and this industry consumes a significant amount of natural sources, raw materials and energy. It generates large volumes of wastewater that adversely affects fresh water resources. Water pollution from the pulp and paper industry includes total suspended solids (TSS), biological oxygen demand (BOD), toxicity, and color (Abbasi and Abbasi, 2003). Due to this fact, minimizing the negative environmental impact of this sector is important.

The aim of this study is to analyze pulp and paper industry in environmental aspects and to develop options for minimizing the environmental impact of the industry.

Within this study, brief information about pulp and paper industry is given and possible cleaner production (CP) options in the sector are introduced. In addition to that, implications of European Union (EU) Integrated Pollution Prevention and Control Directive (IPPC) on pulp and paper industry are discussed.

During this study, process steps of pulp and paper manufacturing were investigated with giving special emphasis on waste generation. Issues of sustainable development and environmental management instruments were studied and cleaner production concept was investigated in details with examples from pulp and paper industry. The EU IPPC directive and reference document on pulp and paper industry was studied briefly. Effects of IPPC directive on the competitiveness power of the sector in Europe and in Turkey were determined, and possible interaction of the directive with other environmental management instruments was discussed.

In the beginning of the study, a survey was conducted and characteristics and profile of the Turkish pulp and paper industry were tried to be identified in many aspects. Structure of the technical questionnaire is given in Table 1.3. The full technical questionnaire in Turkish can be seen in Appendix A.

Table 1.3 Structure of the technical questionnaire

Sections	Sub-Sections			
Company Profile	Communication info	Company status	Certification	Annual capacity
Production Profile	Raw materials and additives	Water usage	Steam usage	Energy usage
Wastes	Solid wastes	Aqueous wastes	Treatment plant	Gaseous wastes
Cleaner Production Awareness	Present status	Awareness on CP opportunities	Willingness to implement CP	Following emerging technologies
Following Cleaner Production Activities	Participation to technical fairs	Following technical periodicals	Training of the staff	Participation to scientific events

The questionnaire was sent to 41 companies. Although only 8 answers were received for this technical questionnaire, some idea about the industry can be driven. Results of this survey were presented in the following sections of the text. It was a goal to conduct a case study in one of the Turkish pulp and paper companies. Several initiations through different paths were started to get in touch with companies and convince them about conducting a case but unfortunately none of the companies gave a positive answer.

When the literature on this subject is screened, it was found out that pulp and paper industry is an important sector where environmental impact minimization is focused both in developed and developing countries (Abbasi and Abbasi, 2003; Luken, 2004; Clayton et al., 1999). In addition to universities and scientific institutions, many national and

international organizations have studies on the subject (EPA, 2002; BREF, 2001). Debate on IPPC Directive is a hot topic and many studies are being conducted about the implications of the directive on pulp and paper industry (ENAP, 2004; Honkasalo, 2003; IPTS, 2001; Larsson and Telle, 2005).

This thesis is a final text of the study where all appropriate information and results are provided. The thesis starts with brief information about pulp and paper industry where overview of the industry in the aspects of economy and technology, pulp and paper production processes, environmental aspects of pulp and paper production and profile of the Turkish pulp and paper industry are mentioned.

Following that, the idea of sustainable development is introduced and the important environmental management instruments are mentioned. Among those, the cleaner production concept is dealt in details and cleaner production opportunities in pulp and paper industry is exemplified.

In the next section, detailed information on IPPC directive is provided and progress on IPPC directive in Turkey is discussed. Information about reference document for the pulp and paper industry is provided and implications of the directive on the industry's development are discussed.

The final section consists of case studies conducted in different countries in which cleaner production opportunities are implemented and economic and environmental benefits are reported.

During the completion of this study, midway findings were presented in an international congress (Arslan and Cesur, 2004a) and a national congress (Arslan and Cesur, 2004b) and in a national technical project exhibition event (Demirel et al., 2004).

2. PULP AND PAPER INDUSTRY

In this section, a very brief overview about pulp and paper industry will be given with providing information about the different processes. Information about the environmental impact of the industry will be provided in general manner and the profile of the Turkish pulp and paper industry will be introduced.

2.1 Industry Overview

Businesses in the paper industry range from wood processors and sawmills to large integrated pulp and paper mills and joinery manufacturing and merchandising. The industry produces a wide range of paper products like paperboard, paper containers and stationery. The industry's diversity is reflected in the mixed pattern of restructuring and development in recent years.

The global pulp and paper industry is dominated by a few large players, and this sector is capital intensive and relies in economies of scale for competitive advantage. Recycling facilities and plantation resources are now the main sources of fiber for pulp and paper. There has been substantial investment in recent years. The pulp and paper market is presently moving into a new investment cycle. This offers new and expanding opportunities for countries with resources.

In developed societies the use of a multitude of paper and board-based products is everyday reality for most people. Paper, as we know it today has been in existence for over two thousand years, and is competing successfully with modern electronic information media and advanced plastic and composite packaging materials. A look at the main functional uses of paper and board shows the diversity of products.

The consumption of paper and board is strongly related to living standards and over long-term periods there is a strong correlation between the increase in the consumption of these products and the growth in the GNP (Gross National Product) and there is a considerable variation in the world-wide consumption of paper per capita. Even within Europe there are big differences. The European countries with the highest paper consumption are Germany (23.4%), United Kingdom (17.5%), France (14.3%), Italy (12.6%), Spain (7.9%) and Netherlands (4.8%). It is expected that EU countries that are now below the EU average would increase their paper consumption to reach the present average (BREF, 2001). It can be predicted that paper manufacturing will be a growth industry for years to come. Overview of Turkish pulp and paper industry will be given later in the study.

Pulp and paper industries are going through a process of consolidation and globalization, which has not yet reached a more stable status. The concentration process will lead to a reduction of companies. As a result of these moves, the industry's structure is changing markedly. In last 25 years the number of paper machines in Europe has been reduced by about 60% while the total capacity has almost doubled. Many companies have grown by investing in new capacity but also by consolidating a large number of small obsolete paper and board mills (BREF, 2001). Thus, the European Paper Industry comprises a relatively small number of very large multi-national groups at one end of the scale yet a large number of small businesses at the other. The large number of relative small sized mills has developed niche strategies on the market.

There has been a significant change in the ownership structure in the last 10 years. Typical features in this development have been the concentration of producers into bigger companies and the integration of paper mills with the overseas pulp producers or acquisitions or financial cooperation relationships between European and overseas manufacturers.

Companies from the United States, the Republic of South Africa or Indonesia have been integrated in or have established closer business relationships with European paper and board manufacturers.

Likewise, there have been more regional and local integration trends inside some countries like Sweden and Finland. This reflects the global nature of the pulp and paper business today. By 2010 it is anticipated that the major markets of the USA, Europe and Japan are joined by Asia and in particular China and Indonesia (BREF, 2001). Southeast Asian markets are likely to grow and lead the world's paper consumption. International trade in paper and papermaking fiber will probably continue to be a feature of the industry with growth continuing in all main production regions. The fastest growth will be seen in the paper and paperboard trade as countries with surplus of fiber add value before exporting.

Dominating pulp producers are the industrialized countries of the Northern Hemisphere; USA, Canada, Sweden, Japan and Finland. In Europe, Finland and Sweden, in particular, largely rely upon the revenue from exports of pulp and paper products. This is due to the high "nativeness" of these products where very little import is needed in order to support the production. These countries are also leading paper products exporters. Export figures of selected countries is tabulated in Table 2.1 (WRI, 2004).

Table 2.1 2004 export figures for paper products (tones)

Canada	15,351,596	Sweden	10,211,125
Finland	12,707,785	USA	8,933,549
Germany	11,525,000	France	5,511,581

2.2 Process Description

The production of pulp and paper can be divided into three major processing steps: pulping, bleaching and paper production (Smook, 2002). Figure 2.1 illustrates the manufacturing steps of paper production.

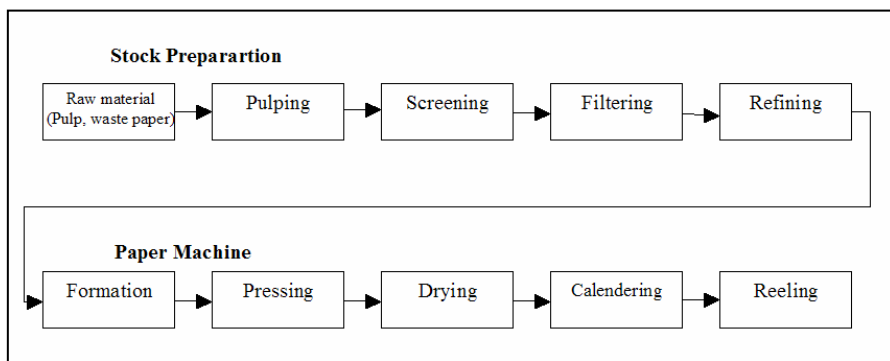


Figure 2.1 Manufacturing steps of paper production

2.2.1 Pulping process

This process breaks down the wood structure by destroying the lignin that holds the wood fibers together. The pulping process begins with wood preparation and handling. Wood preparation consists of a series of operations that convert wood into wood chips by chemical pulping or short blocks for ground wood pulping. The type of pulping process and the amount of bleaching agent used depend on the nature of the feedstock and the desired qualities of the end product (Noyes, 1993). In the pulping process, wood is reduced to a fibrous mass by pulping chemically, mechanically or semi-chemically.

A. Chemical pulping

Chemical pulps are typically manufactured into products that have high quality standards or require special properties. Chemical pulping degrades wood by dissolving the lignin bonds holding the cellulose fibers together. Generally, this process involves the cooking/digesting of wood chips in aqueous chemical solutions at elevated temperatures and pressures. There are two major types of chemical pulping currently used Kraft/soda pulping and sulfite pulping. These processes differ primarily in the chemicals used for digesting.

Kraft (or sulfate) pulping process is the most widely used chemical pulping process. The success of the process and its widespread adoption are due to several factors. First, because the Kraft cooking chemicals are selective in their attack on wood constituents, the pulps produced are notably stronger than those from others. The Kraft process is also flexible, in so far as it is amenable to many different types of raw materials (hard or soft woods) and can tolerate contaminants frequently found in wood. Lignin removal rates are high in the Kraft process — up to 90% — allowing high levels of bleaching without pulp degradation. Finally, the chemicals used in Kraft pulping are readily recovered within the process, making it very economical and reducing potential environmental releases. The Kraft process uses a sodium-based alkaline pulping solution (liquor) consisting of sodium sulfide (Na_2S) and sodium hydroxide (NaOH) in 10% solution. This liquor (white liquor) is mixed with the wood chips in a reaction vessel (digester). The output products are separated wood fibers (pulp) and a liquid that contains the dissolved lignin solids in a solution of reacted and unreacted pulping chemicals (black liquor). The black liquor undergoes a chemical recovery process to

regenerate white liquor for the first pulping step. Overall, the Kraft process converts approximately 50% of input furnish into pulp.

Sulfite pulping process is used much less than the Kraft process. Softwood is the predominant furnish used in sulfite pulping processes. However, only non-resinous species are generally pulped. The sulfite pulping process relies on acid solutions of sulfurous acid (H_2SO_3) and bisulfite ion (HSO_3^-) to degrade the lignin bonds between wood fibers. Sulfite pulps have less color than Kraft pulps and can be bleached more easily, but are not as strong. The efficiency and effectiveness of the sulfite process is also dependent on the type of wood furnish and the absence of bark. For these reasons, the use of sulfite pulping has declined in comparison to Kraft pulping over time.

B. Semi-chemical pulping

Semi-chemical pulp is often very stiff, making this process common in corrugated container manufacture. This process primarily uses hardwood as furnish. The major process difference between chemical pulping and semi-chemical pulping is that semi chemical pulping uses lower temperatures, more dilute cooking liquor or shorter cooking times, and mechanical disintegration for fiber separation. At most, the digestion step in the semi-chemical pulping process consists of heating pulp in sodium sulfite (Na_2SO_3) and sodium carbonate (Na_2CO_3). Other semi-chemical processes include the Permachem process and the two-stage vapor process. The yield of semi-chemical pulping ranges from 55 to 90%, depending on the process used, but pulp residual lignin content is also high so bleaching is more difficult.

C. Mechanical pulping

Mechanically produced pulp is of low strength and quality. Such pulps are used principally for newsprint and other non-permanent paper goods. Mechanical pulping relies on physical pressure instead of chemicals to separate furnish fibers; however, chemicals are sometimes added at the various stages of refining. There are 5 different processes present for mechanical pulping.

The **stone groundwood process** simply involves mechanical grinding of wood in several high-energy refining systems. The **refiner mechanical process** involves refining wood chips at atmospheric pressure while the **thermo-mechanical process** uses steam and pressure to soften the chips before mechanical refining. In the **chemi-mechanical process**, chemicals can be added throughout the process to aid the mechanical refining. The **chemi-thermo-mechanical** process involves the treatment of chips with chemicals for softening followed by mechanical pulping under heat and pressure. Mechanical pulping typically results in high pulp yields, up to 95% when compared to chemical pulping yields of 45-50%, but energy usage is also high. To offset its structural weakness, mechanical pulp is often blended with chemical pulp.

D. Secondary fiber pulping

Throughout the world, consumption of fiber from recovered paper is growing more than twice as fast as overall fiber consumption. Secondary fibers are usually presorted before they are sold to a pulp and paper mill. If not, secondary fibers are processed to remove contaminants before pulping occurs. Common contaminants consist of adhesives, coatings, polystyrene foam, dense plastic chips, polyethylene films, wet

strength resins, and synthetic fibers. In some cases, contaminants of greater density than the desired secondary fiber are removed by centrifugal force while light contaminants are removed by flotation systems. Centrifugal cleaners are also used to remove material less dense than fibers (wax and plastic particles). Inks, another contaminant of secondary fibers, may be removed by heating a mixture of secondary fibers with surfactants. The removed inks are then dispersed in an aqueous media to prevent redeposition on the fibers. Continuous solvent extraction has also been used to recover fibers from paper and board coated with plastics and/or waxes. Secondary fiber pulping is a relatively simple process. The most common pulper design consists of a large container filled with water, which is sometimes heated, and the recycled pulp. Pulping chemicals (such as NaOH) are often added to promote dissolution of the paper or board matrix. The source fiber (corrugated containers, mill waste, etc.) is dropped into the pulper and mixed by a rotor. Debris and impurities are removed by two mechanisms: a ragger and a junker. The ragger withdraws strings, wires, and rags from the stock secondary fiber mixture. A typical ragger consists of a few "primer wires" that are rotated in the secondary fiber slurry. Debris accumulates on the primer wires, eventually forming a "debris rope" which is then removed. Heavier debris are separated from the mixture by centrifugal force and fall into a pocket on the side of the pulper. The junker consists of a grappling hook or elevator bucket. Heat, dissolution of chemical bonds, shear forces created by stirring and mixing, and grinding by mechanical equipment may serve to dissociate fibers and produce a pulp of desired consistency. Contaminant removal processes depend on the type and source of secondary fiber to be pulped. Mill paper waste can be easily repulped with minimal contaminant removal. Recycled post-consumer newspaper, on the other hand, may require extensive contaminant removal, including deinking, prior to reuse.

2.2.2 Bleaching process

Bleaching is defined as any process that chemically alters pulp to increase its brightness. Bleached pulps create papers that are whiter, brighter, softer, and more absorbent than unbleached pulps. Bleached pulps are used for products where high purity is required and yellowing (or color reversion) is not desired (e.g. printing and wrapping papers, food contact papers). Unbleached pulp is typically used to produce boxboard, linerboard, and grocery bags. Any type of pulp may be bleached, but the type(s) of fiber furnish and pulping processes used, as well as the desired qualities and end use of the final product, greatly affect the type and degree of pulp bleaching possible. Printing and writing papers comprise approximately 60% of bleached paper production. The lignin content of a pulp is the major determinant of its bleaching potential. Pulps with high lignin content (e.g., mechanical or semi-chemical) are difficult to bleach fully and require heavy chemical inputs. Excessive bleaching of mechanical and semi chemical pulps results in loss of pulp yield due to fiber destruction. Chemical pulps can be bleached to a greater extent due to their low (10%) lignin content. Typical bleaching processes for each pulp type are detailed below.

Chemical pulp bleaching has undergone significant process changes since approximately 1990. At that time, nearly every chemical pulp mill that used bleaching incorporated elemental chlorine (Cl_2) into some of its processes. Because of environmental and health concerns about dioxins, pulp mills now use elemental chlorine free (ECF) and total chlorine free (TCF) bleaching technologies. The difference between ECF and TCF is that ECF may include chlorine dioxide (ClO_2) and hypochlorite (HClO , NaOCl , and $\text{Ca}(\text{OCl})_2$) based technologies.

Chemical pulp is bleached in traditional bleach plants where the pulp is processed through three to five stages of chemical bleaching and water washing. The number of cycles is dependent on the whiteness desired, the brightness of initial stock pulp, and plant design. Bleaching stages generally alternate between acid and alkaline conditions. Chemical reactions with lignin during the acid stage of the bleaching process increase the whiteness of the pulp. The alkaline extraction stages dissolve the lignin/acid reaction products. At the washing stage, both solutions and reaction products are removed. Chemicals used to perform the bleaching process must have high lignin reactivity and selectivity to be efficient. Typically, 4-8% of pulp is lost due to bleaching agent reactions with the wood constituents cellulose and hemicellulose, but, these losses can be as high as 18%.

Semi-chemical pulps are typically bleached with hydrogen peroxide (H_2O_2) in a bleach tower.

Mechanical pulps are bleached with hydrogen peroxide (H_2O_2) and/or sodium sulfite (Na_2SO_3). Bleaching chemicals are either applied without separate equipment during the pulp processing stage, or in bleaching towers. Full bleaching of mechanical pulps is generally not practical due to bleaching chemical cost and the negative impact on pulp yield.

De-inked secondary fibers are usually bleached in a bleach tower, but may be bleached during the repulping process. Bleach chemicals may be added directly into the pulper. The following are examples of chemicals used to bleach de-inked secondary fibers: hypochlorite (HClO , NaOCl , $\text{Ca}(\text{OCl})_2$), hydrogen peroxide (H_2O_2), and hydrosulfite ($\text{Na}_2\text{S}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$).

2.2.3 Paper production process

Pulp, which may come from on-site production or be purchased from outside vendors, is prepared into paper stock. Chemical additives such as dyes, clays, and thickeners are mixed into the stock to form desired product characteristics. Paper production step can be divided into two parts: the wet end and the dry end. During the wet end operations, the processed pulp is converted into a paper product with a paper production machine, the most common of which is the Fourdrinier paper machine. In the Fourdrinier system, the pulp slurry is deposited on a moving wire belt that carries it through the first stages of the process. Water is removed by gravity, vacuum chambers, and vacuum rolls. This wastewater is recycled to the slurry deposition step of the process due to its high fiber content. The continuous sheet is then pressed between a series of rollers to remove more water and compress the fibers. Then comes the dry end operation where the paper fibers begin to bond together as steam heated rollers compress the sheets. In the calender process the sheet is pressed between heavy rolls to reduce paper thickness and produce a smooth surface. Coatings can be applied to the paper at this point to improve gloss, color, printing detail, and brilliance. Lighter coatings are applied on-machine, while heavy coatings are performed off-machine. The paper product is then spooled for storage.

2.3 Environmental Impact Of Pulp And Paper Industry

2.3.1 Wastes generated

Pulp and paper industry consumes a significant amount of natural sources, raw materials and energy. Due to this fact, the amount of waste generated and the environmental impact of the sector becomes important.

Major sources of pollutant releases in pulp and paper manufacture are at the pulping and bleaching stages respectively.

Aqueous wastes

A typical pulp and paper mill uses 15 to 50 m³ of water per ton of pulp produced in developed countries that are using new technologies and environmentally sound manufacturing processes. General water pollution concerns for pulp and paper mills are effluent solids, biological oxygen demand, toxicity, and color. Toxicity concerns arise from the presence of chlorinated organic compounds such as dioxins and furans. Table 2.2 summarizes the potential sources of water pollutants.

Table 2.2 Potential aqueous pollutants and their sources in pulp and paper industry.

Source	Pollutant
Water used in wood handling/debarking and chip washing	Solids, BOD, color
Chip digester and liquor evaporator Condensate	Concentrated BOD, reduced sulfur compounds
"White waters" from pulp screening, thickening, and cleaning	Large volume of water with suspended solids, significant BOD
Bleach plant washer filtrates	BOD, color, chlorinated organic compounds
Paper machine water flows	Solids
Fiber and liquor spills	Solids, BOD, color

Gaseous wastes

Emissions of various toxic air pollutants are released during the pulping, bleaching and paper making processes. These pollutants include organic sulfur gasses in the form of Total Reduced Sulfur (TRS), sulfur

dioxide, nitrogen oxides and particulate matter. Table 2.3 summarizes the sources of the gaseous pollutants in pulp and paper industry. In the pulp and paper industry, the Kraft pulping process is the most significant source of air pollutants. Also, water vapors are the most visible air emission from a pulp and paper mill, but are not usually regulated unless they are a significant obscurement or climate modifier.

Table 2.3 Potential gaseous pollutants and their sources in pulp and paper Industry

Source	Pollutant
Kraft recovery furnace	Fine particulate, nitrogen oxides
Fly ash from hog fuel and coal-fired burners	Coarse particulate
Sulfite mill operations	Sulfur oxides, ammonia
Kraft pulping and recovery processes	Reduced sulfur gases
Chip digesters and liquor evaporation	Volatile organic compounds
Pulp drying (non-integrated mills)	Volatile organic compounds
All combustion processes	Nitrogen oxides

Solid wastes

The significant residual waste streams from pulp and paper mills include wastewater treatment sludge, lime mud, lime slaker grits, green liquor dregs, boiler and furnace ash, scrubber sludge, and wood processing residuals. Because of the tendency for chlorinated organic compounds to partition from effluent to solids, wastewater treatment sludge is a significant environmental concern for the pulp and paper industry.

2.3.2 Water and energy usage and conservation in pulp and paper industry

Pulp and paper industry consumes much energy and water. And also, this industry is noted for a great percentage of the energy cost in the total production cost. It is extremely difficult to grasp the energy consumption pattern in the entire pulp and paper industry. Since the pulp process differs considerably depending on production items and composition of the material woods, it is difficult to define the representative pulping process.

Energy conservation in the pulp, paper, and wood products industry is typically the result of process technology advancements and diligence in manufacturing operations. Energy intensity in the pulp and paper industry varies according to the chemical and mechanical processes used for wood pulp manufacturing. In the pulp and paper sector, energy conservation practices typically include optimization in the following major areas: indirect steam process heating, steam condensate recovery, process water and secondary heat recovery, electrical co-generation, electrical and steam mechanical drives, variable speed electrical drives, process vessel insulation, waste and renewable fuel usage, and boiler steam and flue gas temperature.

On the other hand, the sector consumes a considerable amount of water but it is very well possible to reduce the amount of water used and to reduce the pollution of water. A much-used option is to let the water be part of a closed system, a cyclic process, in which all water is cleaned and going back into the factory. Attention has to be paid to the fact that one process may need less clean water than another process, so the waste water of the last process may be useful for the first process (cascade). An example is to use the water, which returns from the sieving phase. It is also possible to bleach in a closed system. The water needed for the

bleaching is not disposed of, but stays in the system. Thus, organic and chemical substances are not emitted into the water. The water is not disposed of after the several bleaching and washing steps, but is brought back into the process, after purifying and recovery of the chemicals. These chemicals can also be used again. The use of water decreases from 150 m³/ton pulp to 50 m³/ton pulp when switching from an open water system to a closed system. The common problem in closed water systems is the microorganism appearance and that can be prevented by using suitable chemicals.

2.4 Pulp and Paper Industry in Turkey

Pulp and paper industry has been developed in Turkey increasingly in the last two decades. There are 41 manufacturing companies in Turkey with a total annual capacity of about 2.5 million tons of paper. Table 2.4 summarizes the capacity, production and consumption figures of Turkish pulp and paper industry (SKSV, 2005). Among these 41 companies, 18 are members of the sector's roof organization, Selüloz ve Kağıt Sanayii Vakfı (SKSV, Cellulose and Paper Industry Foundation). Turkish pulp and paper producers are tabulated in Table B.1 in Appendix B.

The difference between the consumption and production figures is an indication that Turkey imports considerable amounts of paper. This difference and the built capacity figures also show that there is a great development potential in pulp and paper industry. Turkey has an export volume of about 10% of the total production in the sector.

The number of employees in state-owned companies decreased dramatically in the last 5 years and also due to automation and technological improvements the rate of qualified workers with respect to unqualified workers has increased in both private and state companies.

The distribution of raw materials used for paper manufacturing in Turkey are 40% wood, 37% recycled paper, 13% imported cellulose, and 10% straw and linen (Ergin, 1999). Since all forestry land in Turkey is state-owned, the private sector is unable to produce paper from wood. Recently, a private company, Mopak, started eucalyptus plantation near Dalaman.

Table 2.4 Capacity, production and consumption figures of Turkish pulp and paper industry

	Capacity (tones)	Production (tones)	Consumption (tones)
Newsprint	182,500	21,000	522,169
Printing Paper	380,500	342,366	793,704
Packaging Paper	39,000	23,477	126,739
Corrugated Board Paper	1,174,500	922,629	1,347,752
Kraft Sack Paper	75,000	43,318	103,435
Carton	443,400	396,095	662,745
Hygienic Paper	197,500	195,472	168,212
Cigarette & Thin Papers	15,000	7,500	15,392
Total	2,507,400	1,951,857	3,740,148

Nearly 40% of the Turkish paper and carton consumption is compensated by imported paper. This is mainly because of the low production cost in developed countries and the reduced customs and taxes in EU countries with respect to Turkey after joining the Customs Union. In fact the overall paper import is increasing every year but, when the paper types are individually, investigated the trend is not the same. For instance, the import rate in newsprint paper increased in 1997, but in 1998 there is a decrease of 24.2% due to a promotion trend in Turkish media resulting in a demand for domestic newsprint paper (DPT, 2000). Another important point is that the corrugated board import highly depends on the economic situation in Turkey and in the world, since it is related with all industrial sectors. Also the decreasing import rate in Kraft sack paper ended in 1998 because a Turkish firm invested in a company abroad. As it is seen, the import numbers and trends mainly depend on extra-ordinary situations rather than capacity, technology, or price facts. The imported raw materials in the sector are raw wood, sulfite cellulose, sulfate cellulose, wood pulp and waste paper (DPT, 2000).

The competitiveness power of Turkey, like in all other sectors, in the pulp and paper industry is low due to high electricity and raw material prices. The unit price of electricity in Turkey for the paper industry is US\$ 0.077, and it is about 40 to 80% higher when compared to European countries (DPT, 2000). In addition to this, waste paper usage in Turkey is comparatively low and this results in an increase in raw material costs. Also due to low technology and inefficient machinery, labor cost is very high in Turkish firms. The prevailing three parameters, electricity, raw material and labor cost, makes up about the 75% of the product cost in Turkey, whereas this is only 50% in European countries (DPT, 2000). All these factors decrease the competitiveness power of Turkish companies. The graphical representation of the production costs of different paper types is given in Figure 2.2.

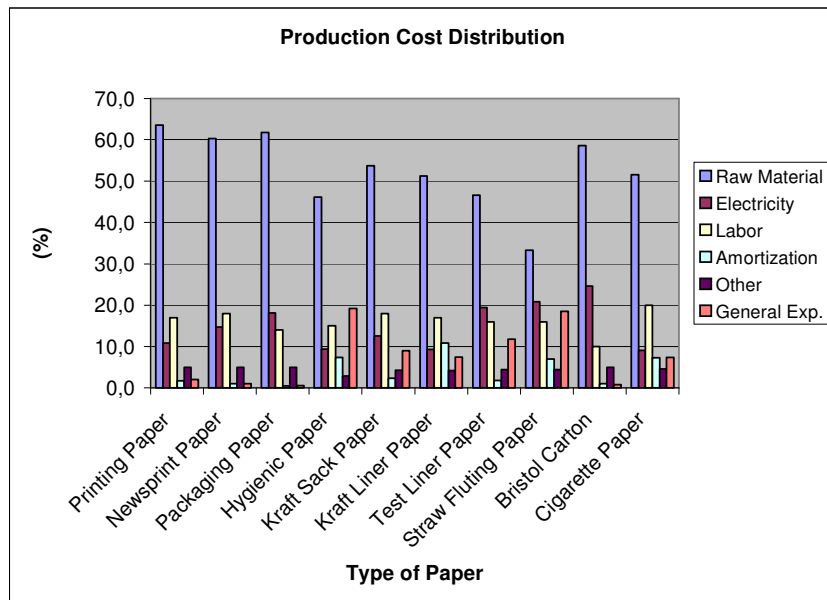


Figure 2.2 Production cost distribution of different paper types in Turkey

Consequently, the export potential of Turkish pulp and paper companies are rather low with respect to other countries. The production costs are the most important parameter for this low competitiveness power of Turkish firms. It is rather difficult for Turkish firms to compete with the integrated and technologically advanced European firms unless Turkish government changes electricity price and taxation policies and the companies improve their production technology. Despite this, the export rate began to increase slowly in Turkey and this should be in a continuous increment.

When compared to foreign companies; production capacities, machine speeds and machine widths of Turkish companies are very low, and this prevents the Turkish companies to operate in optimum

conditions, resulting high production costs. Following Table 2.5 indicates the relationship between mill capacity and production cost (Usta, 2005).

Table 2.5 Relationship between mill capacity and production cost

Capacity (tones/day)	Cost Index (1 ton of pulp)
250	100
500	67
800	55
925	50
1000	47

The development of pulp and paper industry in Turkey strongly depends on the ability to produce high quality, low cost pulp. For this reason; technologically advanced, high capacity mechanical and chemical pulp facilities should be established. Also forestry industry should be developed and private sector should be allowed to take part in the forestry industry. Waste paper recovery rate should be increased. R&D and innovation culture should be promoted by the governmental bodies to encourage Turkish companies develop their own technologies.

It can be stated that technological improvements and application of cleaner production opportunities in Turkish firms would result in very significant cost decreases in the industry since raw materials and electricity prices are high. This will increase the competitiveness power of Turkish companies resulting a decrease in paper import volumes and in the long-term increase in export volumes.

In 2005, pulp and paper industry developed more than expected, but there was a capacity loss in some paper types due to the closure of public SEKA mills (SKSV, 2005).

The stock composition in general contains 66% recycled paper, 30% chemical pulp and 4% fillers in Turkey.

As mentioned in the previous section of the text, a survey was conducted to identify the characteristics of Turkish pulp and paper industry. Only 8 answers were received from companies and although this number is not very sufficient to derive representative results, it gives a rough idea about the sector.

All of the companies (8) use underground water as water source where one company uses river water and one company uses municipality water supply in addition to underground water for manufacturing purposes. Specific water consumption values are shown in Figure 2.3 for 8 mills.

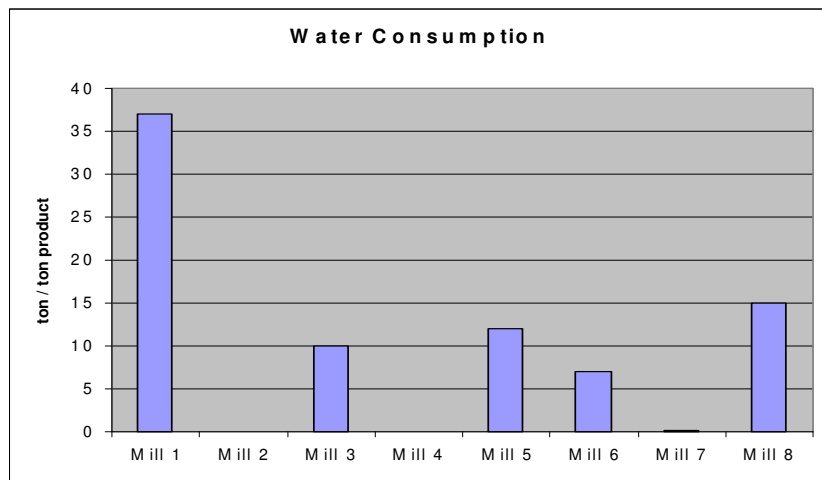


Figure 2.3 Specific water consumption values of responded companies (No responses for this question from Mill 2 and Mill 4)

Seven mills produce their own steam and only one company buys steam from a neighboring company. Natural gas and fuel oil are dominating fuels used in boiler rooms. Distribution of fuel types used for

steam production is illustrated in Figure 2.4 and steam loss percentages in steam cycle are illustrated in Figure 2.5.

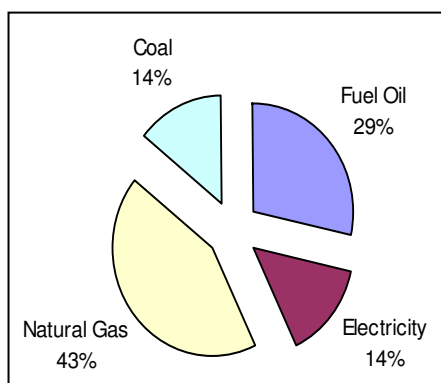


Figure 2.4 Distribution of fuel types used for steam production

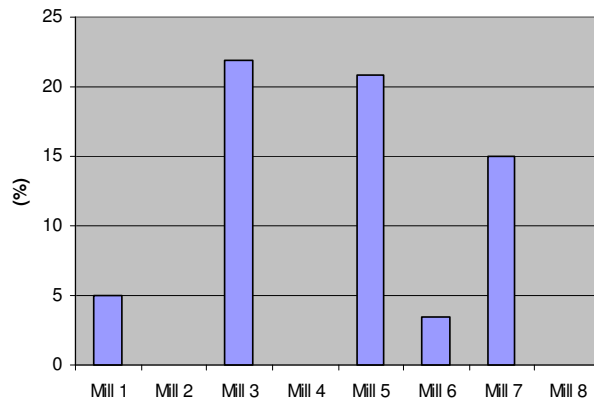


Figure 2.5 Steam loss percentages of responded companies (No responses for this question from Mill 2, Mill 4 and Mill 8)

Waste water emission values vary a lot from mill to mill and most of the companies seem to comply regulatory values for BOD (40 mg/L) and COD (100 mg/L) values. Figures 2.6 and 2.7 show values for these parameters, respectively.

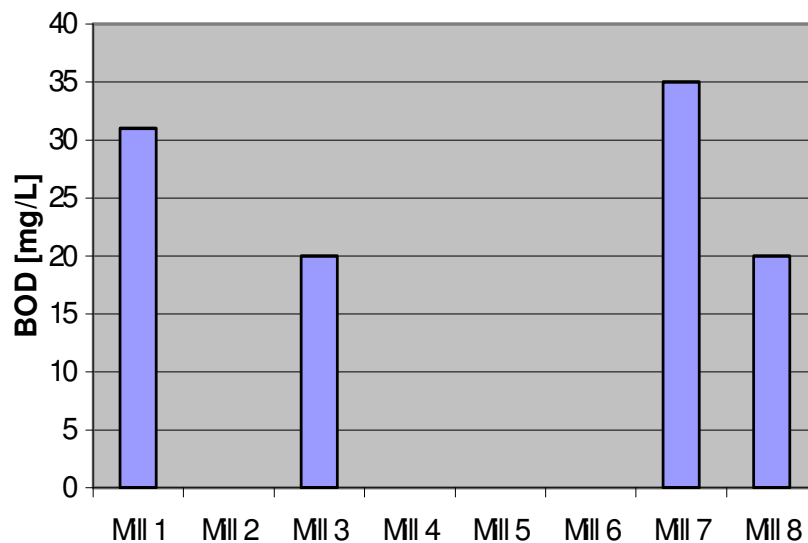


Figure 2.6 BOD values of responded companies (No responses for this question from Mill 2, Mill 4, Mill 5 and Mill 6)

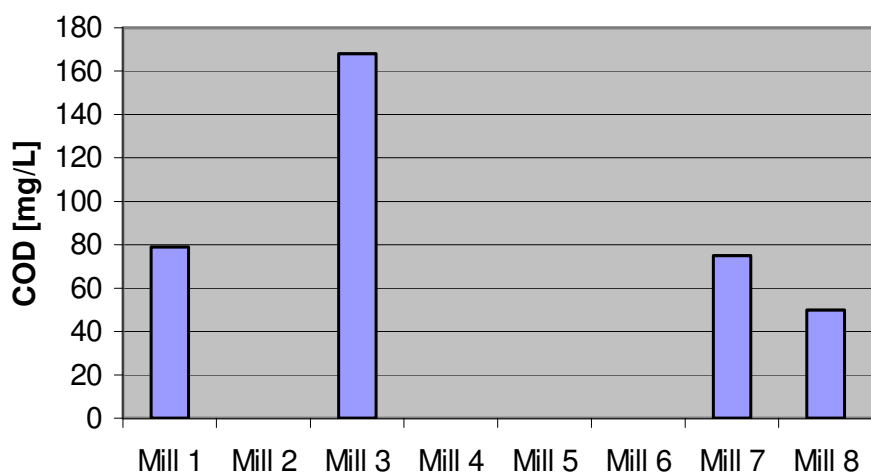


Figure 2.7 COD values of responded companies (No responses for this question from Mill 2, Mill 4, Mill 5 and Mill 6)

Specific energy consumption values of responded firms are given in Figure 2.8.

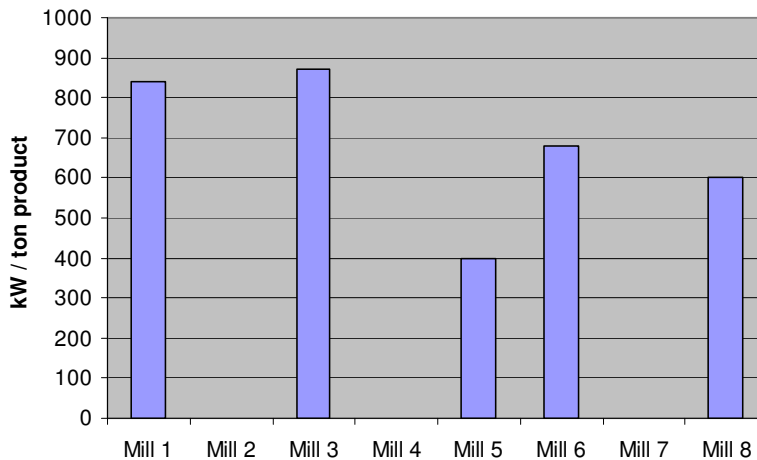


Figure 2.8 Specific energy consumption values of responded companies (No responses for this question from Mill 2, Mill 4 and Mill 7)

Apart from these technical questions, the questionnaire asks questions that the responders is asked to self-evaluate the environmental performance of their company and give information about the activities done in the company for the improvement of environmental performance. As extracted from these answers;

- All of the responders believe that they meet regulatory emission values.
- All of the responders believe that the production line needs to be improved for a decrease in waste generation and energy usage.
- About half of the responders believe that the mill has problems about waste and pollution parameters.

- Almost all of the responders believe that the mill managers and workers follow the technological developments in the environmental field.
- Less than half of the responders believe that the mill assigns budget for environmental improvements and R&D facilities.
- More than half of the responders believe that environmental performance can only be improved with huge investments and needs a lot of effort.
- More than half of the responders believe that environmental performance of the mill can be improved with small investments and non-cost techniques.
- All of the responders believe that it is applicable to cooperate with Turkish universities about the application of cleaner production technologies.
- All of the responders believe that it is applicable to cooperate with national or international non-governmental organizations about the application of cleaner production technologies.

3. SUSTAINABLE DEVELOPMENT

In this section, the idea of sustainable development will be introduced briefly. Following that, selected environmental management instruments will be given with a special emphasis on cleaner production and its implications in pulp and paper industry.

All human activities are linked to consumption and production, a fact which has been reflected in the demand for natural sources on the one hand, and pollution of the environment on the other. According to United Nations Development Program (UNDP) (2003), the repercussions of unsustainable human consumption and production have been growing increasingly evident in the forms of regional and global environmental problems such as climate change, stratospheric ozone depletion, acidification, loss of biodiversity, freshwater pollution and increasing waste generation.

It is essential that all these environmental problems be addressed and minimized or even eliminated. In order this to be done; we must understand at least to a certain extent the ways in which particular human activities affect the environment and human health. Highly polluting industries, energy production, neglected nuclear safety, agriculture, forestry, tourism and individual households are the main sources of pollution in today's world.

It is necessary for us to take effective steps to counteract the global problems that we confront. In dealing with them, we should find new solutions to our own problems, and help to secure our own future. Environmental concerns are getting more and more advanced. In 1960s, waste treatment was considered only after the plant having been constructed; in 1980s, waste treatment has gained consideration before the construction of plant; in 2000s, the incorporation into R&D phase is

achieved where pollution prevention became popular (Yang and Shi, 2000).

Looking at the relations between the environment and human activities, and vice versa, it is indisputable that environmental degradation may have serious implications in terms of human health, poverty, economic development, and even national security. Improved understanding of these issues is one of the preconditions for achieving overall support and participation in preventive measures, which have been shown to be the most efficient method in terms of linking environment protection with economic and social development.

While there are now hundreds of operational definitions of sustainable development, most are variations of that put forward by the World Commission on Environment and Development (the Brundtland Commission) in their 1987 **Our Common Future** report:

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within in two key concepts:

- *The concept of "needs", in particular the essential needs of the world's poor, to which overriding priority should be given; and*
- *The idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.*

Thus the goals of economic and social development must be defined in terms of sustainability in all countries - developed or developing, market-oriented or centrally planned. Interpretations will vary, but they must share certain general features and must flow from a

consensus on the basic concept of sustainable development and on a broad strategic framework for achieving it.

Development involves a progressive transformation of economy and society. A development path that is sustainable in a physical sense could theoretically be pursued even in a rigid social and political setting. But physical sustainability cannot be secured unless development policies pay attention to such considerations as changes in access to resources and in the distribution of costs and benefits. Even the narrow notion of physical sustainability implies a concern for social equity between generations, a concern that must logically be extended to equity within each generation. More specifically, sustainable development requires, in the words of the report:

- a political system securing citizen participation in decision making,
- an economic system that is able to generate surpluses and technical knowledge on a self-reliant and sustained basis,
- a social system that provides for solutions for the tensions arising from disharmonious development,
- a production system that respects the obligation to preserve the ecological base for development,
- a technological system that can search continuously for new solutions,
- an international system that fosters sustainable patterns of trade and finance, and a flexible and self correcting administrative system.

These requirements are more in the nature of goals that should underlie national and international action on development. What matters is the sincerity with which these goals are pursued and the effectiveness with which departures from them are corrected.

3.1 Environmental Management Instruments

The purpose of environmental management instruments is to promote sustainable development in organizations. These instruments bring the idea of proactive approach when dealing with environmental problems. Organizations have traditionally perceived the implementation of environmental measures as a potential economic burden, in particular the investments made to comply with regulations. Environmental management instruments offer flexible solutions for polluters to address environmental issues and change their behavior to a proactive-preventive approach. Different Environmental management instruments have been developed and implemented at various levels of production and consumption. They are intended to assist organizations in reaching their environmental policies, objectives and targets.

3.1.1 Environmental management accounting

Environmental costs are often understood as those related only to pollution treatment. But these are usually only the tip of the hidden iceberg, and costs incurred within the “production of pollution” processes are forgotten. Environmental Management Accounting (EMA) is a tool which helps to identify and adequately quantify these costs; in so doing, it provides a realistic estimation of the “price” of production processes including costs related to meeting environmental commitments.

Better understanding of the structure and nature of environmental costs promotes adoption of prevention approaches within organizations and supports cleaner production measures. Implementation of EMA can be a challenging job and lack of internal data can be a barrier.

3.1.2 Environmental management systems

Environmental Management Systems (EMS) have been introduced to support organizations in their efforts to systematically and efficiently manage environmental impacts under their influence. They enable an organization of any size or type to control the impact of its activities, products or services on the natural environment.

ISO 14000 is a series of international, voluntary environmental management standards. These standards are being developed with the following principles in mind: they must result in better environmental management, they must be applicable in all nations, they should promote the broad interests of the public and the users of the standards, they should be cost effective, non-perspective, and flexible, to allow them to meet the differing needs of organizations of any size worldwide, they should be sustainable for internal and external verification, they should be scientifically based and, they should be practical, useful and useable.

The eco – management and audit scheme (EMAS) allows voluntary participation in an environmental management scheme for organizations in the European Union and the European Economic Area. The scheme has been operative since April 1995. The overall objective of the European Community is in particular to “promote a harmonious and balanced development of economic activities, sustainable and non-inflationary growth respecting the environment and rising of standards of living and quality of life” (Vig and Axelrod, 1999).

3.1.3 Environmental labeling

Environmental labeling (EL) and declaration is a market-based voluntary instrument. It is linked to the fact that consumers in many countries are becoming increasingly aware of the environmental and health impacts of different products to buy. The major purpose of environmental labeling is twofold: to promote the design, production, marketing, and use of consumer products and services that have a reduced environmental impact during their entire life-cycle; and to provide consumers with better information on the environmental quality of products and services, and to help them make informed environmental choices in their purchases. The principle of EL application is that products that meet environmental criteria are awarded the right to use a specific logo on their packaging. This logo can be displayed as a marketing tool to show consumers that a given product has a superior environmental performance. In order to ensure the reliability of labels, formalized schemes, including mechanisms are developed. Usually either governments or multi-stakeholder institutions design and operate labeling schemes. EL supports market development in a desirable way by encouraging research and development of innovative, clean technologies.

European Union eco label flower is a unique certification scheme, pictured in Figure 3.1, aimed to help European consumers distinguish greener, more environmental friendly products and services and established in 1992. This concept discloses the food and medicine industry. The EU Eco-label is administered by the European Eco-labeling Board (EUEB) and receives the support of the European Commission, all Member States of the European Union and the European Economic Area (EEA) (Ergün, 1999). The Eco-labeling Board includes representatives

such as industry, environment protection groups and consumer organizations. Paper products are included in this concept and, the EU Eco-label Flower tells us that:

This paper product has been manufactured using special recycled fibers, virgin fibers come from sustainably managed forests, and air emissions of sulfur and CO₂ and water pollution have been limited during production.



Figure 3.1 The EU Eco-Label Flower

3.1.4 Life cycle analysis

Life Cycle Analysis (LCA) is a technique for assessing the environmental performance of a product, process or activity from “cradle to grave” (Azapagic, 1999). LCAs identify and quantify the process flows and systems that are major contributors to environmental degradation. This is important for identifying the areas for improvement that will have the greatest influence on total life cycle impacts. Unlike some pollution prevention techniques that are centered around single issues such as recycling capacity or reduced toxicity, LCA considers a range of environmental impact categories. Furthermore, while typical

approaches to environmental protection select the most efficient and cost-effective processes before determining ways of reducing environmental impacts, environmental considerations are part of the decision-making process from the beginning when using LCA (Burgess and Brennan, 2001). LCA is made up of four phases in sequence:

1. Goal and scope assessment: The purpose of the study is described in this phase. This description includes the intended application and audience, and clearly states the reasons for carrying out the study. The scope of the study is described, which includes limitation, the functions of the systems investigated, the functional unit, the systems investigated, the system boundaries, the allocation approaches, the data requirements, the key assumptions, the impact assessment method, the interpretation method and the type of reporting.

2. Inventory analysis: Data is collected and interpreted, calculations are made and the inventory results are calculated and presented. Mass flows and environmental input and output flows are calculated and presented.

3. Impact assessment: The production system is examined from an environmental perspective using category indicators, such as global warming, acidification and eutrophication. The life cycle impact categories and examples are tabulated in Table 3.1.

4. Interpretation: The results are analyzed in relation to the goal of the study. Conclusions are drawn, limitations of the results are presented and recommendations are provided based on the findings of the preceding phases. The conclusions should be compatible with the goals and quality of the study.

Table 3.1 LCA Impact Categories

Global Impact	Regional Impact	Local Impact	Other
- Use of resources (renewable and non-renewable), water and land - Greenhouse effect - Ozone degradation in stratosphere - Release of persistent toxic substances	- acidification of water and soil - waste disposal/landfill	- human toxicity - eco-toxicity - photochemical ozone creation	- use of land (transportation) - noise - unpleasant odor

3.1.5 Easy-to-use tools

Eco-mapping is an original and simple tool that helps small companies during environmental management implementation developed by Heinz Werner Engel. It is an inventory of practices and problems and a practical method for conducting an environmental review. It can be regarded as a do-it-yourself tool that allows employees' involvement and participation. It is also the basis of the environmental documentation in the company. The application of eco-mapping depends on the empty lay-out figures of the manufacturing site. The applier draws the important points and unsuitable situations on six empty maps and those six empty maps are for; water, soil, air and odor, energy, waste and risks subjects. At last, the data on six maps are collected and the situation of the plant is identified (SBA, 2002a).

Environmental self-diagnosis guide helps to raise awareness among executive managers on the opportunity of development and improvement through a better inclusion of the environment in the overall management. By identifying the environmental aspects of their activities, products or services, the companies can undertake more easily voluntary actions to control their environmental problems in accordance with ISO 14001. It is a practical tool, composed of movable cards that are filled in according to the questions asked about the impact of the enterprise on the environment. It allows making an analysis of the adequacy between the priority environmental aspects of the activities, products or services of the company (self-evaluation) and the current dispositions of the company as regards organization and management (self-diagnosis). A practical action plan can then be established by putting together the self-diagnosis and the self-evaluation. The Guide was developed by Entreprises pour l'Environnement (EPE, France) with the participation of the French Agency for Environment and Energy Management (ADEME, France) and Algae Management (SBA, 2002b).

3.2 Cleaner Production

Industrial production systems require resources: *materials* from which products are made, *energy* which is used to transport and process materials, as well as *water* and *air*. Present production systems are *linear* or cradle-to-grave, often using hazardous substances and finite resources in vast quantities and at fast rates.

The goal of Clean Production (CP) is to fulfil our need for products in a *sustainable way* i.e. using renewable, non-hazardous materials and energy efficiently while conserving bio-diversity. Clean Production systems are *circular*, as illustrated in Figure 3.2, and use

fewer materials and less water and energy. Resources flow through the production-consumption cycle at slower rates. In the first place, a Clean Production approach questions the very need for the product or looks at how else that need could be satisfied or reduced.

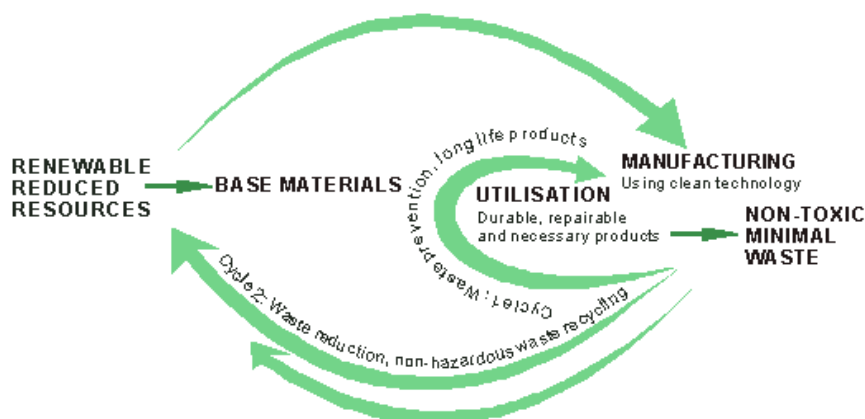


Figure 3.2 Circular system of the Cleaner Production concept

Clean Production implements the Precautionary Principle - it is a new holistic and integrated approach to environmental issues centered on the product. This approach recognizes that most of our environmental problems - for example global warming, toxic pollution, loss of biodiversity - are caused by the way and rate at which we produce and consume resources. It also acknowledges the need for public participation in political and economic decision-making.

According to UNEP, TIE (United Nations Environment Program, Division of Technology, Industry and Environment) which coined the term in 1989, the definition of Cleaner Production is:

Cleaner Production is the continuous application of an integrated preventive environmental strategy applied to processes, products and

services to increase efficiency and reduce risks for humans and the environment. It applies to:

- **production processes:** conserving raw materials and energy eliminating toxic raw materials and reducing the quantity and toxicity of all emissions and wastes
- **products:** reducing negative impacts along the life cycle of a product from raw materials extraction to its ultimate disposal
- **services:** incorporating environmental concern into designing and delivering services

Cleaner Production requires changing attitudes, responsible environmental management, creating conducive national policy environments and evaluating technology options.

Thus, Cleaner Production is an approach to environmental management that aims to improve environmental performance by focusing on the cause of environmental problems rather than the results. By doing this it is different to the traditional 'pollution treatment and control' approaches. Cleaner Production is a pro-active, 'anticipate and prevent' philosophy.

Cleaner Production, as can be seen from the definition, can not only be applied to production processes, but it can also be applied throughout the life cycle of a product, from the initial design phase, through to the consumption and disposal phase. It aims to ensure conservation of resources, the elimination of toxic raw materials, and the reduction of wastes and emissions. Five common generic techniques for implementing Cleaner Production include improved housekeeping practices, process optimization, raw material substitution, new technology or new product design.

Besides preserving environmental values, an important feature of Cleaner Production is that by preventing inefficient use of resources and

avoiding unnecessary generation of waste, companies benefit from reduced operating costs, reduced waste treatment and disposal costs and reduced liability, among many other savings. Investing in Cleaner Production, to prevent pollution and reduce resource consumption is usually more cost-effective than continuing to rely on increasingly expensive 'end-of-pipe' solutions thus offers a “win-win” solution (Clayton et al., 1999).

Thus the concept of Cleaner Production is an all-embracing strategy which is directed towards reducing environmental impacts and risks by considering minimization of pollution at source by a diverse range of activities. There are a number of analogous terms for Cleaner Production, such as eco-efficiency, green productivity and pollution prevention, among others, with slightly different focuses. The four elements of cleaner production the following:

1. The Precautionary Approach: This approach puts the burden of proof on the potential polluter to prove that a substance or activity will do no environmental harm, rather than on communities having to prove harm. This approach rejects the sole use of quantitative risk assessment in decision making because it recognizes the limitations of scientific knowledge in determining if the use of a chemical or an industrial activity should proceed. This approach does not ignore science but rather acknowledges that since industrial production also has social impacts, other public decision-makers - not just scientists - must be involved.

2. The Preventative Approach: It is cheaper and more effective to prevent environmental damage than to attempt to manage or 'cure' it. Prevention requires going upstream in the production process to prevent the source of the problem instead of attempting damage control downstream. Pollution prevention replaces pollution control. For

example, prevention requires process and product changes to avoid the generation of incinerable waste streams, instead of more sophisticated incinerator design. Similarly, demand and supply side energy efficiency practices replace the current over-emphasis on the development of new fossil fuel energy sources.

3. Democratic Control: Clean Production involves all those affected by industrial activities, including workers, consumers and communities. Access to information and involvement in decision-making ensures democratic control. As a minimum, communities must have information on industrial emissions and access to pollution regulations, toxic use reduction plans, as well as data on product ingredients.

4. Integrated and Holistic Approach: Society must adopt an integrated approach to environmental resource use and consumption. Currently, environmental management is fragmented allowing pollutants to be transferred between air, water and soil. Reductions in polluting emissions from production processes lead to the hazard being transferred to the product. These dangers can be minimized by addressing all material, water and energy flows, the whole life cycle of the product, and the economic impact of the change to Clean Production. The tool used to assist in maintaining a holistic approach is the Life Cycle Analysis that was discussed above. An integrated approach will be essential to ensure that as hazardous materials are phased-out, for example PVC, they are not replaced by materials that pose new environmental threats.

Since cleaner production is said to be a “win-win” solution, there are a number of benefits to industry by preventing, minimizing, or reducing pollution. These benefits can be categorized as follows.

Economic: One of the significant benefits of industrial pollution prevention is that is often a very economical approach. When wastes are reduced or eliminated, cost savings can be realized, by reduced expenditures for pollution control equipment, and lower disposal costs. Closely examining the manufacturing processes needed to plan a successful pollution prevention approach can produce a number of side benefits as well, such as significant improvements in energy and water conservation, and improved, or more consistent, product quality. Waste handling costs have escalated exponentially in the last decade. In some firms, substantial source reduction activities have been implemented with minor capital expenditures, with resultant payback within six months.

Liability: Frequently the dominant cost savings come from reduced future liability for the pollution. Waste producers have been subjected to the possibility of unlimited liability for any harm caused by their wastes. This liability includes even future problems caused by wastes currently managed using the best-known practices. Because waste site cleanups can cost hundreds of millions of dollars each, these liabilities can dwarf all other costs associated with waste generation, which makes pollution prevention options even more compelling. Another important advantage is reduced liability related to workplace safety.

Improving Effectiveness: Pollution prevention reduces the risk inherent in managing the waste streams and residues that result from traditional control methods. For example, the most effective solution for lead, asbestos, and certain pesticides has been to ban their use. Prevention approaches also avoid the potential risk of control technology failure, and the problems associated with effective operation and maintenance.

Avoiding uncertainty: Understanding exposure and health effects and the inevitable questions concerning the cost, effectiveness, and reliability of treatment make pollution prevention to surest way to eliminate the risk inherent in any release of pollutants into the environment. When there is an opportunity to eliminate risk, the public is often unwilling to accept the results of efforts to determine an acceptable risk level.

Multi – media transfer: Pollution prevention avoids the inadvertent transfer of pollutants across media that may occur with end-of-pipe media-specific treatment and control approaches.

Resource protection: By avoiding excessive levels of wastes and residues, minimizing the depletion of resources, and assuring that the environment's capacity to absorb pollutants is not exceeded, pollution prevention can protect natural sources for future generations.

Improved image: Pollution prevention actions generally looked upon favorably by the public in this age of “community right to know” laws and increased public inspection of industrial practices. Public involvement can have an important effect on a company's activities.

Energy consideration: Energy-saving techniques should be considered as pollution prevention, from the standpoint that energy-savings result in less power being produced off-site, or on-site, with resultant decreased pollution at the power plant.

3.2.1 Clean technologies versus pollution control technologies

To become more eco-efficient, a company may invest in new technology. Environmental technologies are categorized as clean technologies or pollution control technologies. The environmental and economic impacts of these two types of technologies differ. Pollution control technologies are distinct stand-alone units that are added to the production process.

They capture and/or treat emissions. Clean technologies are technologies used to produce goods and services - their primary objective is non-environmental. Environmental considerations have been taken into account in their design or application to reduce the environmental impacts. The possibilities to solve environmental problems with pollution control technologies are limited. Clean technologies address environmental impacts at source, whereas pollution control technologies only treat emissions that have already been created.

Costs and benefits of clean technology and pollution control technology are realized at different times. In long term, the adoption of clean technology is more economically beneficial due to related savings etc. It may also involve increased product quality and other benefits. The initial investment may however be larger. Pollution control technologies tend to look more attractive if the investment is assessed in short term. However, they may reduce the manufacturing performance of the plant. From the point of view of eco-efficiency, clean technology appears superior in many respects. However, the adoption of pollution control technology has often been industry's response to increased environmental demands (Honkasalo, 2003).

3.2.2 Cleaner production assessment procedure

Industry and businesses respond to the business environment, and especially to those signals, which are perceived to be impacting them either beneficially or adversely. It is this mix of threats and opportunities that conditions the corporate behavior.

The Cleaner Production assessment methodology is used to systematically identify and evaluate the Cleaner Production opportunities and facilitate their implementation in industries.

The main steps of a Cleaner Production assessment are outlined below. This procedure is useful in organizing the Cleaner Production program in a company and bringing together persons to be involved with the development, evaluation, and implementation of Cleaner Production measures.

Cleaner Production assessment is most often divided in five phases. It should be noted that the same methodology could be applied to reduce risks and energy consumption. The algorithm of the assessment procedure is illustrated in Figure 3.3 and detailed below.

3.2.2.1 Planning and organization

Planning and organization starts once one or a few persons in the company become interested in Cleaner Production. A Cleaner Production assessment can be initiated after a conscious decision has been made by the management to take action. Experience from a growing number of companies show that the following elements are important for the successful start of a Cleaner Production program:



Figure 3.3. Algorithm of the Cleaner Production assessment procedure

Management commitment: Plant management has to set the stage for Cleaner Production activities, in order to ensure collaboration and participation. Management commitment may be reflected in environmental policy statements, however, the actual behavior of the management is at least equally important as written statements.

Employee involvement: Management should set the stage, but whether or not good Cleaner Production opportunities are found is largely dependent on the collaboration of employees. Employees, in particular those involved in the daily operations and maintenance on the shop-floor, have often key understanding of why wastes and emissions are generated, and are often able to come up with solutions.

Cost awareness: It is important in the sense that proper cost information can convince management, as well as employees, that producing cleaner can make money. Unfortunately, many companies, in particular small

and medium sized enterprises, do not know how much money is wasted. Typically, only costs charged by external waste contractors are taken into consideration Actual waste costs can be significantly more.

An organized approach is necessary to identify, evaluate and implement Cleaner Production opportunities. Cleaner Production assessments are undertaken with a view to avoid or at least reduce the generation of waste and emissions. Moreover, it is expected that these options will in turn change existing management and information systems, and thus support and facilitate further Cleaner Production activities:

Organize a project team: The project team initiates, co-ordinates and supervises the assessment activities. In order to be effective, the project team should have enough process knowledge to analyze and review the present production practices, enough creativity to develop and evaluate changes for the current production practices, and enough authority to implement and maintain the proposed changes in the production practices.

Identify barriers and solutions: In order to develop workable solutions, the project team should identify the site-specific barriers to Cleaner Production implementation that might exist.

Set plant-wide goals: Plant-wide Cleaner Production goals set the stage for the assessment and should challenge the project team. The tendency of companies to underestimate the Cleaner Production potential in the first place is often reflected in comparatively low goals.

Cleaner Production planning is a systematic, comprehensive method for identifying options to reduce or avoid the generation of waste. The Cleaner Production planning process itself also has its own results and benefits:

- A careful planning process can ensure the selection and implementation of the most cost-effective Cleaner Production options.
- Systematic planning ensures that Cleaner Production objectives and activities are consistent with those identified in the organization's broader planning process.
- Effective Cleaner Production planning facilitates broader business planning investment analysis and decision-making (such as capital budgeting and purchasing).
- A documented Cleaner Production plan may be a condition for receiving financing or insurance at better rates.

3.2.2.2 Assessment procedure

During the Assessment Phase the material balance is studied, and appropriate measures are proposed to reduce or prevent loss of materials.

During the phase the project team uses all means possible to identify Cleaner Production options. The ideas for options may come from a literature search, personal knowledge, discussions with suppliers, examples in other companies, specialized data bases, or some further R&D. Brainstorming is an indispensable tool to ensure creative intellectual environment to think of all possibilities.

Generating options is a creative process that relies more on inspiration than on logical deduction (although logic remains important).

The brainstorming session is a combination of creativity and 'common sense'. Before starting a brainstorming session, literature or other organizations and companies should be consulted, and a site inspection should take place so the generation of options will be more productive. One should, hereby, focus on all influences of the process that could lead to the generation of wastes and emissions. Brainstorming sessions have proved to be most effective when managers, engineers, process-operators and other employees as well as some outside consultants work together without hierarchical constraints.

It should be noted that during a Cleaner Production assessment a number of obvious possibilities for immediate improvements might already have been identified. In order to go further, it is often helpful to conceptually divide the process into three essential elements: source identification followed by cause diagnosis, and option generation.

- For the **source identification**, an inventory is made of the material flows, entering and leaving the company with the associated costs. This results in a process flow diagram, allowing for the identification of all sources of waste and emission generation.
- Next is the **cause diagnosis**: an investigation of the factors that influence the volume and composition of the waste and emissions generated. A checklist of possible causes of waste generation is used to assess all possible factors influencing the volume and/or composition of the waste stream or emissions. A material and energy balance is needed for the evaluation of the relative importance of each of the possible waste generation causes.
- The purpose of the next logical step (**option generation**) is to create a vision on how to eliminate or control each of the causes of waste and emission generation. The generic prevention

practices specified before are used to develop appropriate Cleaner Production options. After Cleaner Production options have been identified, they are evaluated following the same procedure used for evaluation of other investments or technical innovation options. The option generation consists of several elements, as figured in Figure 3.4. The option generating process then considers each element in turn.

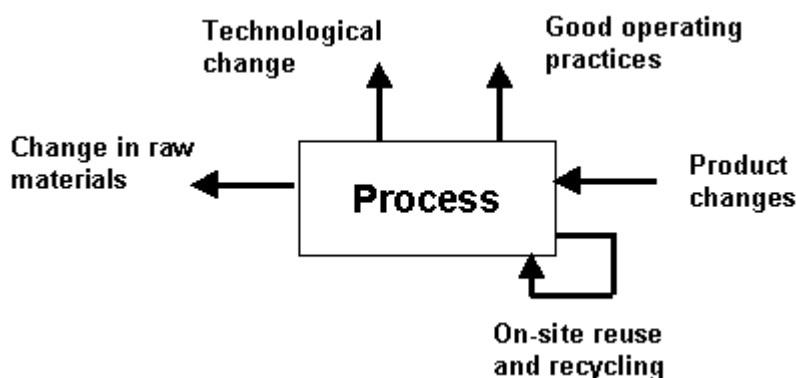


Figure 3.4 Elements of option generation in assessment procedure

Change in raw materials accomplishes Cleaner Production by reducing or eliminating the hazardous materials that enter the production process. Also, changes in input materials can be made to avoid the generation of hazardous wastes within the production process. Input material changes include material purification and material substitution.

Change in technology is oriented towards process and equipment modifications to reduce waste and emissions, preliminary in a production setting. Technology changes can range from minor changes that can be

implemented in a matter of days at low cost, to the replacement of processes involving large capital costs. These include the following:

- Changes in the production process
- Modification of equipment, layout, or piping
- Use of automation
- Changes in process conditions, such as flow rates, temperatures, pressures, and residence times

Good operating (good housekeeping) practices also referred to as good housekeeping practices, imply procedural, administrative, or institutional measures that a company can use to minimize waste and emissions. Many of these measures are used in industry largely as efficiency improvements and good management practices. Good operating practices can often be implemented with little cost. These practices can be implemented in all areas of the plant, including production, maintenance operations, and in raw material and product storage. It is an important fact to consider that 50% of waste can be reduced by adopting Good housekeeping practices and making small operational changes (SBA, 1998).

Good operating practices include the following:

- Management and personnel practices: Includes employee training, incentives and bonuses, and other programs that encourage employees to conscientiously strive to reduce waste and emissions.
- Material handling and inventory practices: includes programs to reduce loss of input materials due to miss-handling, expired shelf life of time-sensitive materials, and proper storage conditions.
- Loss prevention minimizes wastes and emissions by avoiding leaks from equipment and spills.

- **Waste segregation:** these practices reduce the volume of hazardous wastes by preventing the mixing of hazardous and non-hazardous wastes.
- **Cost accounting practices:** include programs to allocate waste treatment and disposal costs directly to the department or groups that generates wastes and emissions, rather than charging these costs to general company overhead accounts.
- **Production scheduling:** By analyzing these factors, the departments or groups that generate wastes and emissions become more aware of the effects of their treatment and disposal practices, and have a financial incentive to minimize their wastes and emissions. By judicious scheduling of batch production runs, the frequency of equipment cleaning and the resulting wastes and emissions can be reduced.

Product changes are performed by the manufacturer of a product with the intention of reducing waste and emissions resulting from a product's use. Product changes include:

- Changes in quality standards
- Changes in product composition
- Product durability
- Product substitution

Product changes can lead to changes in design or composition. The new product can thus have less environmental impacts throughout its life cycle: from raw material extraction to final disposal.

On-site recycling or reuse involves the return of a waste material either to the originating process as a substitute for an input material, or to another process as an input material. Generating appropriate prevention options is a creative step; the information collected is used as guidance in

this creative process. The most important items to consider within this process are:

- Find facts (seek all information relevant to the problem)
- Identify the problem (gradually broadening the problem formulation by asking questions how and why)
- Generate ideas to solve the problems (traditional brainstorming)
- Define criteria to be used to select solutions/ideas
- Screening of ideas/options
- Select all ideas/options that may be implemented immediately

3.2.2.3 Feasibility studies

The feasibility studies have to prove whether each of the (non-obviously feasible) options is technically and economically feasible and whether it contributes to the environmental improvement.

The feasibility studies can be divided into five tasks discussed below.

Preliminary Evaluation: The options are sorted in order to identify additional evaluation needs. Managerial options do not always require a technical evaluation, while equipment-based options do. Similarly, simple options normally do not require an environmental evaluation, while complex options do. Finally, cheap options do not require a detailed economic evaluation, while expensive options may.

Technical Evaluation: The technical evaluation consists of two interrelated parts. First, it should be evaluated whether the option can be put in practice. This requires a check on the availability and reliability of

equipment, the effect on product quality and productivity, the expected maintenance and utility requirements and the necessary operating and supervising skills. Second, the changes in the technical specifications can be converted into a projected materials balance, reflecting the input and output material flows and energy requirements after implementation of the cleaner production option. The options that do not need capital expenditure, e.g. housekeeping measures, can often be implemented quickly. It is a typical fast-track approach. If capital investment is needed for the chosen option, it is advisable to appoint an ad-hoc group of experts, to make a technical evaluation based on selected evaluation criteria. Raw material, equipment or process changes are expensive and may effect changes in production line or product quality. Therefore, technical evaluation of such option requires more complex investigation.

Economic Evaluation: The economic evaluation consists at least of data collection (regarding investments and operational costs, and benefits), choice between evaluation criteria (pay back period, Net Present Value (NPV) or Internal Rate of Return) and feasibility calculations. The economic data collection builds upon the results of the technical evaluation. In order to properly incorporate the long-term economic advantages of cleaner production, it is highly recommendable to apply Total Cost Assessment principles to the economic evaluation (especially for high cost options).

Environmental Evaluation: The objective of environmental evaluation is to determine the positive and negative impacts of the option for the environment. An environmental evaluation must take into account the whole life-cycle of a product or service. There are essentially two types of life-cycle analyses: quantitative and qualitative. The quantitative method involves developing a set of criteria against which the

environmental impact of a product can be measured and then actually measuring it against these criteria. Criteria may be developed using parameters such as: the cost of disposal or clean-up of the wastes generated at all stages in the life-cycle; the amount or cost of energy used at all stages in the life cycle; etc. The other, qualitative approach is more useful for this assessment. It involves drawing up a matrix of environmental issues versus life cycle stages.

Selection of Feasible Options: First, the technically non-feasible options and the options without a significant environmental benefit can be eliminated. All remaining options can in principle be implemented. However, a selection is required in case of competing options or in case of limited funds.

3.2.2.4 Implementation and continuation

In the last phase, the feasible prevention measures are implemented and provisions taken to ensure the ongoing application of Cleaner Production. The development of such an ongoing program requires monitoring and evaluation of the results achieved by the implementation of the first group of prevention measures.

The expected result of this phase is threefold:

- Implementation of the feasible Cleaner Production measures
- Monitoring and evaluation of the progress achieved by the implementation of the feasible options
- Initiation of ongoing Cleaner Production activities

To achieve this result, the following tasks should be implemented:

- **Prepare Cleaner Production Plan:** The measures are organized according to the expected date of implementation. Additionally, the person or department with the prime responsibility for the implementation should be identified.
- **Implement Feasible Cleaner Production Measures:** The effort needed to implement Cleaner Production measures can vastly differ substantially. Simple measures (like good housekeeping) can easier be implemented. However, the focus should be on complex measures, which require a substantial investment (high cost options). Implementation of these options can require a detailed preparation such as planning the installation and funding requirements. Next, the installation of equipment requires supervision in order to safeguard optimal use of the new facilities.
- **Monitor Cleaner Production Progress:** Simple indicators should be used to monitor progress and to keep the management as well as other interested parties frequently informed. The choice of the measurement method is crucial. It can be based on changes in waste (and/or emission) quantities, changes in resource consumption (including energy) or changes in profitability. The evaluation of the monitoring data should include changes in the production output and/or changes in the product mix.
- **Sustain Cleaner Production:** The ongoing application of the Cleaner Production concept may require structural changes in the organization and management system of the company. The key areas are: integration into the technical development of the company, proper accountability of waste generation, and

employee involvement. The integration into the technical development could include preventive maintenance schedules, integration of environmental criteria (such as energy and resource consumption) in the selection of new equipment or integration of Cleaner Production into long-term research and development plans. Employee involvement can be achieved by staff education, creation of regular opportunities for two-way internal communication and employee reward programs.

3.2.3 Barriers to cleaner production

Despite attractive economics and significant reductions in environmental impacts, the widespread adoption of Cleaner Production still remains limited. Several studies have addressed the barriers for the adoption of Cleaner Production at the level of individual enterprises, and most often categorized these as:

Financial

- High cost of external capital for investments in industry
- Lack of funding mechanisms (lending schemes etc.) appropriate for Cleaner Production investments
- Perception that investments in Cleaner Production present a high financial risk due to the innovative nature of Cleaner Production
- Cleaner Production not properly valued by credit providers in their evaluation procedures for lending, equity participation etc.

Economic

- Cleaner Production investments are not sufficiently cost effective (compared with other investment opportunities), given present resource prices

- Immaturity of the company's internal cost calculation and cost allocation practices
- Immaturity of the company's internal capital budgeting and capital allocation procedures.

Policy – related

- Insufficient focus on Cleaner Production in environmental, technology, trade and industry development and strategies
- Immaturity of the environmental policy framework (including lack of enforcement, etc.).

Technical

- Absence of a sound operational basis (with well established production practices, maintenance schemes etc.)
- Complexity of Cleaner Production (e.g., need to undertake comprehensive assessment to identify appropriate Cleaner Production opportunities)
- Limited accessibility of equipment supportive to Cleaner Production (e.g., high quality engineering small wares for process instrumentation)
- Limited accessibility of reliable technical information tailored to the company's needs and assimilative capacities.

Organizational

- Lack of leadership for environmental affairs
- Perceived management risk related to Cleaner Production (e.g., no incentives for managers to put their efforts into implementation of Cleaner Production)
- Immaturity of the environmental management function in the company's operations

- (General) immaturity of the organization structure of the company and its management and information systems
- Limited experience with employee involvement and project work.

Conceptual

- Indifference: perception regarding the own role in contributing to environmental improvement
- Narrow interpretation or misunderstanding of the Cleaner Production concept
- (General) resistance to change.

3.2.4 Process synthesis

The systematic design of chemical processes, commonly called “Process Synthesis” has received much attention in the engineering literature. Process synthesis is an act of determining the optimal interconnection of processing units as well as the optimal type of the design of the units within a process system. The interconnection of processing is called the structure of the process system. When the performance of the system is specified, the structure of the system and the performance of the processing units are not determined uniquely. The task is to select a particular system out of a large number of alternatives that met the specified performance. In reality, process synthesis must be an integral part of process design. Synthesis is difficult since there are a very large number of alternatives. The problem is to choose the optimum process alternative among several possibilities that has the lowest cost, but must also ensure that the process is safe, will satisfy environmental constraints, is easy to start-up and operate. Heuristic can be used to eliminate certain process alternatives from further consideration and also

to show the bottlenecks of the process. Pinch analysis is a thermodynamically oriented heuristic procedure and is used to identify the thermodynamic bottlenecks (pinch points) that limit the extent of heat exchange between hot and cold process streams (heat integration and Heat Exchanger Network Design, HEN) also of mass exchange between the rich and the lean process streams (mass integration and Mass Exchange Network Design, MEN) (Cesur et al., 1997). Energy and water re-use is at the heart of Pinch Technology activities. With the application of Pinch Technology, savings can be achieved in both capital investment and operating cost. Emissions can be minimized and throughput can be maximized. Pinch analysis is a useful tool for obtaining feasible design possibilities without requiring complex mathematical models and powerful software design packages. Then optimum alternative can be searched among these feasible alternatives by the mathematical modeling approach.

3.2.4.1 Energy usage minimization

For the reduction of use of energy in chemical process, there are two alternative approaches present. One is the Pinch Approach and the other is the Second Law of Thermodynamics Approach.

Pinch approach: In the late 1970s Pinch Analysis emerged as a tool for the design of HEN against the background of the energy crisis (Linnhoff, 1994). The Composite Curves, the Grid Diagram of streams and the Pinch are probably best-known three concepts in Pinch Analysis. All these concepts relate to a specific economic level of heat recovery, which needs to be optimized. The Composite Curves are constructed from stream data representing a process heat and material balance. The

Composite Curve allow the designer to predict optimized hot and cold utility targets ahead of design, to understand driving forces for heat transfer, and locate the heat recovery “Pinch”. The Grid Diagram of streams allows the designer to develop heat recovery networks using the Pinch Design Method, a mixture of methodology and engineering judgement.

Second law of thermodynamics approach: The second law of thermodynamics approach uses the Second Law directly and significantly, allows multiple optimal solutions, is applicable to entire processes as well as to HEN, depends on the skills of the designer. This approach is based on the 13 Common-sense Second Law guidelines that are easy to use, deceptively simple and proven to be powerful (Sama, 1995).

3.2.4.2 Water usage minimization

Mass exchange operations have a wide range of applications in the chemical process industries, such as feed preparation, product separation, product finishing and recovery of valuable materials. Mass exchange is also becoming increasingly important in hazardous waste minimization, an industrial activity dictated by growing environmental concerns and regulation. In particular, utilization of recycle/reuse networks for hazardous waste minimization requires the use of mass-exchange operation that can transfer hazardous species from a set of rich streams to a set of lean streams.

Pinch approach: Integrated waste water system design is a complex problem. There may be a large number of process steps and water can be

reused or regenerated in all manner of possible configurations. As a result of reuse and regeneration, the overall water flow rate to the system is reduced. In practical applications, however, there are some constraints. For example, water from one step may not be used in other step, because of the danger of process contamination. Even given these constraints, identifying the correct steps for re-use and regeneration can be nearly impossible. At the same time, reduction of water flow rate is important. A reduction in flow rate decreases both fresh water and effluent treatment cost. Energy costs (pumping), capital costs (piping) and environmental load factors all improve.

Mathematical approach: The mathematical approach for the design of mass-exchange networks applies a set of algorithmic operations for the separation targets. The rationale behind the development of these targets is based on the thermodynamic and combinatorial properties of the problem. The two possible targets in this approach can be the minimum cost of mass separating agents or the minimum number of mass exchange units (Dökmez, 1998).

3.2.5 Cleaner production opportunities in pulp and paper industry

In this section, selected cleaner production opportunities in pulp and paper industry is provided. As mentioned in previous sections of the study, cleaner production options can be implemented as changes in raw materials, changes in technologies, good operating practices, recycling and reuse and product changes. Following example cleaner options are also categorized in the same manner.

Because the pulp and paper industry is highly capital intensive and uses longest usable technologies with long equipment lifetimes, major process-changing pollution prevention opportunities are expensive

and require long time periods to implement. The pulp and paper industry is a dynamic one, however, that constantly makes process changes and material substitutions to increase productivity and cut costs. The trend towards materials substitutions is also reflected in an increasing demand for alternative pulping and bleaching chemicals.

The chemical recovery systems used in chemical pulping processes are an example of pollution prevention technologies that have evolved alongside process technologies. An efficient chemical recovery system is a crucial component of chemical pulping mill operation: the chemical recovery process regenerates process chemicals, reducing natural resource usage and associated costs, as well as discharges to the environment and producing energy. Many recent pollution prevention efforts in the pulp and paper industry have focused on reducing the releases of toxics, in particular, chlorinated compounds. Pollution prevention techniques have proven to be more effective in controlling these pollutants than conventional control and treatment technologies. Most conventional, end-of-pipe treatment technologies are not effective in destroying many chlorinated compounds and often merely transfer the pollutants to another environmental medium. Efforts to prevent chlorinated releases have, therefore, focused on source reduction and material substitution techniques such as defoamers, bleaching chemical or wood chip substitution to reduce the industry's use and releases of chlorinated compounds. Such source reduction efforts and material substitutions usually require substantial changes in the production process. In addition to the major process changes aimed at reducing toxics releases, the industry is implementing a number of pollution prevention techniques to reduce water use and pollutant releases (BOD, COD, and TSS) such as: dry debarking, recycling of log flume water, improved spill control, bleach filtrate recycle, closed screen rooms, and improved storm water management. The pulp and paper industry has also

worked to increase the amount of secondary and recycled fibers used for the pulping process.

3.2.5.1 Cleaner production by changes in technology

Extended delignification further reduces the lignin content of the pulp before it moves to the bleach plant. Because the amount of bleaching chemicals required to achieve a certain paper brightness is proportional to the amount of lignin remaining in the pulp after the pulping process, extended delignification can reduce the amounts of bleaching chemicals needed. A number of different extended delignification processes have been developed. These processes involve: increasing the cooking time; adding the cooking chemicals at several points throughout the cooking process; regulating the cooking temperatures; and carefully controlling the concentration of hydrogen sulfide ions and dissolved lignin. Importantly, the process changes do not degrade the cellulose that would normally accompany increased cooking time. Extended delignification processes have been developed for both batch and continuous pulping processes. The lignin content of the brownstock pulp has been reduced by between 20 and 50% with no losses in pulp yield or strength using such processes (EPA, 2002). In consequence, chlorinated compounds generated during bleaching are reduced in approximate proportion to reductions in the brownstock lignin content. In addition, the same changes have resulted in significant reductions in BOD, COD and color (EPA, 2002). One study demonstrated a 29% decrease in BOD resulting from an extended delignification process. Facility energy requirements have been shown to increase slightly with extended delignification. However, off-site power requirements (associated with decreased chemical use) have been estimated to more than offset the on-site

increases. As of 1993, extended delignification accounted for 20% of worldwide bleached kraft capacity and 21% of U.S. mills. A significant number of changeovers to the process are currently underway (EPA, 2002).

Oxygen delignification also reduces the lignin content in the pulp. The process involves the addition of an oxygen reactor between the kraft pulping stages and the bleach plant. The brownstock pulp from the digester is first washed and then mixed with sodium hydroxide or oxidized cooking liquor. The pulp is fluffed, deposited in the oxygen reactor, steam heated, and injected with gaseous oxygen wherein it undergoes oxidative delignification. The pulp is then washed again to remove the dissolved lignin before moving to the bleaching plant. Oxygen delignification can reduce the lignin content in the pulp by as much as 50% resulting in a potentially similar reduction in the use of chlorinated bleaching chemicals and chlorinated compound pollutants. The process can be used in combination with other process modifications that can completely eliminate the need for chlorine-based bleaching agents. In addition, unlike bleach plant filtrate, the effluent from the oxygen reactor can be recycled through the pulp mill recovery cycle, further reducing the non-pulp solids going to the bleaching plant and the effluent load from the bleach plant. The net effect is reduced effluent flows and less sludge generation. Facility energy requirements have been shown to increase with oxygen delignification, however, the decrease in off-site power requirements (associated with decreased chemical use) have been estimated to exceed the on-site increases resulting in a decrease in overall energy requirements. Also, the recovered energy and reduced chemical use offset the cost (EPA, 2002).

Ozone delignification (ozone bleaching) is now being used in the pulp and paper industry. The technology has the potential to eliminate the need for chlorine in the bleaching process. Ozone delignification is performed using processes and equipment similar to that of oxygen delignification. The ozone process, however, must take place at a very low pH (1.0 to 2.0), requiring the addition of sulfuric acid to the pulp prior to the ozonation. In addition to low pH, a number of process conditions are critical for ozone delignification: organic materials must be almost completely washed out of the brownstock pulp; temperatures must stay at about 20°C; and ozone reactive metals must be removed prior to the ozonation stage. Oxygen delignification and/or extended delignification processes are considered a prerequisite for successful ozone bleaching. When used in combination, the two processes can result in a high quality bright pulp that requires little or no chlorine or chlorine dioxide bleaching. Overall emissions from the combination of the oxygen and ozone processes are substantially lower than conventional processes because effluents from each stage can be recycled. Pilot systems consisting of ozone delignification in combination with oxygen delignification and oxygen extraction have shown reductions in BOD of 62%, COD of 53%, color of 88%, and organic chlorine compounds of 98% (EPA, 2002). However, ozone is unstable and will decompose to molecular oxygen, thus ozone must be generated on-site and fed immediately to the pulp reactor. Ozone generation systems are complex and account for a high percentage of the total costs. Facility energy use will increase due to the on-site production of ozone, however, this energy will be offset by the energy that would normally be used to produce chlorine and chlorine dioxide.

Addition of anthraquinone catalysis to the pulping liquor has been shown to speed up the kraft pulping reaction and increase yield by

protecting cellulose fibers from degradation (EPA, 2002). The anthraquinone (a chemical catalyst produced from coal tar) accelerates the fragmentation of lignin, allowing it to be broken down more quickly by the pulping chemicals. This lowers the amount of lignin in the prechlorination pulp, thus reducing the amount of bleaching chemicals needed. Anthraquinone catalysts are increasingly used in combination with oxygen delignification and extended delignification to overcome boiler capacity bottlenecks arising from these delignification processes.

Performing enzyme treatment of pulp is also a new technology that can replace conventional pulp treatment methods. Biotechnology research has resulted in the identification of a number of microorganisms that produce enzymes capable of breaking down lignin in pulp. Although the technology is new, it is believed that a number of mills are currently conducting enzyme treatment trials. The microorganisms capable of producing the necessary enzymes are called xylanases. Xylanases for pulp bleaching trials are available from several biotechnology and chemical companies. Since enzymes are used as a substitute for chemicals in bleaching pulp, their use will result in a decrease in chlorinated compounds released somewhat proportional to the reduction in bleaching chemicals used. Enzymes are also being used to assist in the deinking of secondary fiber. Researches has identified cellulase enzymes that will bind ink to the smaller fiber particles facilitating recovery of the ink sludge (EPA, 2002). Use of enzymes may also reduce the energy costs and chemical use in retrieving ink sludge from deinking effluent.

Improved brownstock and bleaching stage washing can substantially reduce chemical use and therefore pollution. Liquor solids remaining in the brownstock pulp are carried over to the bleach plant and then compete with the remaining lignin in the pulp for reaction with the

bleaching chemicals. Improved washing, therefore, can reduce the required amount of bleaching chemicals and the subsequent reductions in chlorinated compounds as well as conventional pollutants. Modern washing systems with improved solids removal and energy efficiency are beginning to replace the conventional rotary vacuum washers. State-of-the-art washing systems include: atmospheric or pressure diffusion washers, belt washers, and pulp presses. Opportunities for reduced effluent flows and water use are also present in the bleaching plant. Acid filtrates from hypochlorite or chlorine dioxide stages can be used as dilution and wash water for the first bleaching stage. Similarly, second extraction stage filtrates can be used as dilution and wash water in the first extraction stage (EPA, 2002). Most new mills are designed with these counter-current washing systems and some mills are retrofitting their existing wash systems.

Improved chipping and screening can sustain proper circulation and penetration of the pulping chemicals. Chip uniformity is controlled by the chipper and screens that remove under and oversized pieces. Standard equipment normally does not sort chips by thickness although it has been demonstrated that chip thickness is extremely important in determining the lignin content of pulp. Improper chip thickness can therefore result in increased use of bleaching chemicals and the associated chlorinated compounds and conventional pollutants (EPA, 2002). Some mills are beginning to incorporate equipment that will separate chips according to their thickness as well as by length and width.

3.2.5.2 Cleaner production by good operating practices

Preventing and controlling black liquor spill is a good example for applying good operating practices in a pulp mill. The mixture of dissolved lignin and cooking liquor effluent from the pulping reactor and washed pulp is known as black liquor. Raw black liquor contains high levels of BOD, COD, and organic compounds. Spills of black liquor can result from overflows, leaks from process equipment, or from deliberate dumping by operators to avoid a more serious accident. Spills of black liquor can have impacts on receiving waters, are a source of air emissions, and can shock the microbial action of wastewater treatment systems. Black liquor losses also result in the loss of the chemical and heat value of the material. Systems needed to control black liquor spills are a combination of good design, engineering, and, most importantly, operator training (EPA, 2002). A few elements of an effective spill control system include: physical isolation of pieces of equipment; floor drainage systems that allow spills to be collected; backup black liquor storage capacity; sensors that provide immediate warning of potential or actual spills; and enclosed washing and screening equipment.

Improved chemical controls and mixing can reduce formation of chlorinated organic compounds by avoiding excess concentrations of chlorine-based bleaching chemicals within reactor vessels (EPA, 2002). This can be accomplished by carefully controlling the chemical application rates and by ensuring proper mixing of chemicals within the reactor. Modern chemical application control and monitoring systems and high-shear mixers have been developed which decrease formation of chlorinated organic compounds.

3.2.5.3 Cleaner production by changes in raw materials

Substitution of chlorine dioxide for elemental chlorine as a bleaching agent is gaining widespread use due to its beneficial impacts on pulp and effluent quality. The use of chlorine dioxide in place of chlorine increases the proportion of oxidative reactions thereby reducing the formation of residual chlorinated organic pollutants. Chlorine dioxide bleaching produces about 20 % of the chlorinated compounds produced using elemental chlorine. A substitution of 50 to 70 % in the first bleaching stage has become relatively common in recent years. Chlorine dioxide substitutions approaching 100 % have been shown to increase pulp yields and quality (EPA, 2002). The use of chlorine dioxide, however, is two to four times more expensive than the equivalent oxidizing power using elemental chlorine. Because chlorine dioxide is unstable and cannot be stored, it must be continually generated at the mill. The processes used to manufacture chlorine dioxide generate a number of byproducts that may have environmental impacts, including, spent acids, chlorine gas, salt cakes and acid cakes. A number of alternative chlorine dioxide generation processes are being developed to reduce or eliminate the formation of such byproducts.

4. EU INTEGRATED POLLUTION PREVENTION & CONTROL DIRECTIVE

4.1 IPPC Directive In General

A growing number of countries are using integrated permits, which control all elements of a facility's environmental footprint. Emissions to air, water, and land are comprehensively managed, along with a host of other factors (such as waste generation, raw materials use, energy efficiency, noise, accident prevention, other pollution prevention factors, and risk management). Accounting for the whole facility's environmental impacts, an integrated permit goes beyond simply consolidating applicable media permits; it is intended to promote continually improving performance while ultimately driving the facility to be more sustainable.

Industrial production processes account for a considerable share of the overall pollution in Europe. Therefore the EU formed a set of common rules for permitting and controlling industrial installations, and these rules came into force as the European Council Directive 96/61/EC on integrated pollution prevention and control (The IPPC Directive) in 1996.

The purpose of the Directive is to achieve integrated prevention and control of pollution arising from the industrial and agricultural activities, leading to a high level of protection of the environment as a whole and contributing to sustainable development.

More specifically, the Directive provides for a permitting system for certain categories of installations requiring both operators and regulators to take an integrated, overall look at the polluting and consuming potential of the installation. The integrated approach means

that the permits must take into account the whole environmental performance of the plant, covering e.g. emissions to air, water and land, generation of waste, use of raw materials, energy efficiency, noise, prevention of accidents, and restoration of the site upon closure. Central to this approach is the general principle that operators should take all appropriate preventative measures against pollution, in particular through the application of best available techniques (BAT) enabling them to improve their environmental performance. More information on the BAT concept and determination of BATS will be discussed later in this chapter.

To assist the licensing authorities and companies to determine BAT, the European Commission organises an exchange of information between experts from the EU Member States, industry and environmental organisations. This work is co-ordinated by the European IPPC Bureau of the Institute for Prospective Technology Studies at EU Joint Research Centre in Seville (Spain). This results in the adoption and publication of the BAT Reference Documents (BREFs).

The IPPC Directive is an example of procedural EU legislation. It harmonizes the procedures of issuing environmental permits to a certain extent but does not prescribe emission limits that would be applied uniformly across the EU. Instead, the concept of BAT guides the authorities and companies in choosing how to prevent and control pollution. The flexible approach has been chosen to give the authorities a possibility to take into account the geographical location, local environment and technical characteristics of the installation. The directive aims also taking into account European industry's competitiveness power and innovation potential (Honkasalo, 2003).

To summarize, in order to receive a permit, an industrial or agricultural installation must comply with certain basic obligations. In particular, it must:

- Use all appropriate pollution-prevention measures, namely the best available techniques (which produce the least waste, use less hazardous substances, enable the recovery and recycling of substances generated, etc.);
- Prevent all large-scale pollution;
- Prevent, recycle or dispose of waste in the least polluting way possible;
- Use energy efficiently;
- Ensure accident prevention and damage limitation;
- Return sites to their original state when the activity is over.

About 50,000 installations are covered by the IPPC Directive in the EU at the moment. The IPPC Directive was published in 1996 and as it is a Directive, the Member States are required to incorporate its main principles and objectives in their national laws, but they can themselves choose the methods of implementing the Directive. The Directive was supposed to be transposed into the national laws by October 1999, but there have been some delays in the Member States. The IPPC Directive demands that all installations must have an environmental permit for their activities. New companies must be authorized under the Directive before the start of operation. Existing installations were provided a transition period of eight years to get prepared to meet the requirements of the Directive. They are obliged to meet the requirements latest in October 2007.

At the moment the IPPC Directive is reviewed while not altering the fundamental principles, objectives and ambition of the present

Directive. The core objective of the review is to encourage industry to go beyond regulatory compliance.

Determination of BATs

The term “best available techniques” is defined as “the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole.” Among the terms; “techniques” includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned; “available” techniques are those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator; “best” means most effective in achieving a high general level of protection of the environment as a whole.

When discussed in economic aspects; definition of BAT includes economic filters for the adoption of techniques. For a technique to be available, it has to be “economically viable”. Economically viable has been interpreted as something that does not violate the competitiveness of the industry sector in the European level. Regulators who issue the permits decide what economic viability is, partly based on the information provided by the industry. The BREF document provides them information on what can be considered BAT, but it does not cover all the aspects and details. Information on the costs and benefits was

rarely available in the process of collecting information for the BREF (Honkasalo, 2003). This is an area in IPPC Directive where still discussions are on going.

On the other hand, the principle of continuous improvement is embedded in the IPPC Directive. The concept of BAT is dynamic. Once new techniques become available, BAT changes and BREFs that give information on BAT are updated.

The definition of BAT in the IPPC Directive requires the techniques to be “developed on a scale which allows implementation in the relevant industrial sector”. This definition makes the directive to support diffusion on existing techniques rather than invention of new techniques. Industry can be required to adopt a technique that has been commercialized and proved to be successful.

When discussed in environmental aspects, IPPC supports the adoption of clean technology, because it mentions issues that cannot be solved at the end of pipe. For example, the use of less hazardous substances, low-waste technology and consumption and nature of raw materials are to be taken into consideration when determining BAT.

Link between cleaner production and IPPC

Case specific and integrated approach to pollution prevention and control are the key characteristics of the IPPC Directive. The IPPC Directive strives to call increasing attention to the prevention of pollution on source. In the past, environmental regulation has had a major impact to environmental impacts of industry, but it has mostly driven the adoption of end-of-pipe technologies. If IPPC Directive manages to shift the focus to pollution prevention and cleaner production, there is a possibility that it yields also economic benefits for the industry (Honkasalo, 2003).

Link between environmental management systems and IPPC

Environmental management systems (EMS) are increasingly seen as potentially playing a valuable complementary role in dealing with environmental challenges presented by industrial estates, lifecycle issues and supply chain interactions. In addition to those, EMSs are more and more regarded as integral part of BATS for large installations under IPPC.

A quality EMS also makes it easier for industry to develop permit applications and also for regulators to assess them. A robust management system also makes identifying responsibilities easier and hence helps to address challenges of ‘disintegrating installations’ or synergistic effects with neighboring installations.

These various connections and the realization of these connections lie behind the ‘provocative’ statement earlier of making certified/verified EMSs mandatory for IPPC installations (ENAP, 2004).

4.2 Progress On IPPC Directive In Turkey

As Turkey is developing rapidly and expanding its industrial sector, it faces significant environmental problems. Turkey currently has in place a legal framework for the prevention of pollution and for the control and reduction of emissions and discharges (into air, water and soil) by industry. However, the subject of pollution is dealt with in a rather fragmented way in this legal framework. Another feature is that the licensing system in Turkey is based on the issuing of separate licenses for emissions and discharges into air, water and soil. Hence Turkey has no integrated system in line with EU regulations.

In relation with the accession to EU membership, studies on harmonization of environmental legislation of Turkey with the EU's relevant legislation are being continued with the participation of all relevant parties in Turkey. Harmonization of Turkish environmental legislation and implementation of the IPPC Directive was set to be a short-term goal in the Accession Partnership Document of Turkey in 2003 and to achieve this goal, many projects were held in Turkey with partners from EU Member States.

One of the projects was "Capacity Building on the Adoption and Implementation of Integrated Pollution Prevention and Control Directive (IPPC 96/61/EC)" project that started in 2003 and ended in 2005. Wider objective of the project, with a budget of EUR 525,000, was to assist Turkey with its harmonization efforts of the environmental acquis.

The other two projects were "Institutional strengthening for the adoption and implementation of the Integrated Pollution Prevention and Control Directive" project and "Harmonization of the Integrated Pollution Prevention and Control Directive to Turkish Environmental Legislation" project. The target groups of these projects were the governmental bodies in Turkey, mainly the Ministry of Environment and Forestry. The IPPC Directive is due to be fully implemented by 2015. This implementation is based not only on harmonized national legislation and its enforcement, but also on a complete restructuring of the system and the establishment of a new institutional structure. It is estimated that the Turkish private sector needs a total investment of EUR 14 Billion to implement the necessities of the Directive (Öztürk, 2005).

4.3 BREF Document For Pulp and Paper Industry

Since the production processes in pulp and paper industry varies according to raw materials, and many other parameters; a generally

agreed structure of the sector had to be developed that separates the sector into different classes of mills from an environmental perspective. The BREF describes the most important pulp, paper and board manufacturing processes separately for five main classes:

Kraft Pulp and Paper Mills

Sulphite Pulp and Paper Mills

Mechanical Pulp and Paper Mills

Recycled Fibre Paper Mills

Non Integrated Paper Mills

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 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. In contrast, the list of techniques to consider in the determination of BAT provides a lot of different options of an overall BAT for given mills, which may be combined in different ways.
- The BAT concept is process-related because the environmental impact is caused on this level i.e. by different manufacturing processes as for instance cooking, bleaching, de-inking, coating etc. The performance of each processes, the raw materials used and the product properties to be achieved determine the emission of a mill.

- As pulp and paper products are highly diverse and utilized processes even for one and the same product may vary greatly, many factors of production technology must be taken into account to guarantee a high level of environmental protection. 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.
- There are different options for suitable combinations of processes depending on the product properties to be achieved. 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 the BREF for pulp and paper industry, best available techniques are presented for major mill classes separately.

The BREF document in the pulp and paper industry consists of an introductory section and five major parts separated upon the type of the processes:

- The Kraft pulping process,
- The sulphite pulping process,
- Mechanical pulping and chemi-mechanical pulping,
- Recycled fiber processing, and
- Papermaking and related processes.

Each of these chapters has five main sections according to the general outline of IPPC BAT Reference Documents:

- Applied processes and techniques;
- Major environmental concerns such as resource and energy demand, emissions and waste;
- Description of relevant techniques for emission abatement, waste minimization and energy savings;
- Identification of best available techniques; and
- Emerging techniques.

The discussion of the techniques to consider in determination of BAT all follow the same structure and cover a short description of the technique, main achieved environmental performance, applicability, cross-media-effects, operational experiences, economics, driving forces for implementing this technique, example plants and reference literature. The section on BATs includes ranges of emission and consumption levels that are associated with the use of BAT.

The BREF for the Pulp and Paper Industry represents the information exchange on BAT where 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.

4.3.1 General BAT for all processes

During the information exchange it emerged that the most effective measure for the reduction of emissions/consumption and the improvement of economic performance is the implementation of the best available process and abatement technologies in combination with the following:

- Training, education and motivation of staff and operators;
- Process control optimization;
- Sufficient maintenance of the technical units and the associated abatement techniques;
- Environmental management system that optimizes management; increases awareness and includes goals and measures, process and job instructions etc.

4.3.2 BATS for recycled fiber processing

Recovered fiber has become an indispensable raw material for the paper manufacturing industry because of the favorable price of recovered fibers in comparison with the corresponding grades of virgin pulp and because of the promotion of recovered paper recycling by many European countries. The recovered paper processing systems vary according to the paper grade to be produced e.g. packaging paper, newsprint, testliner, or tissue paper and the type of furnish used.

Generally, recycled fiber (RCF) processes can be divided in two main categories:

- Processes with exclusively mechanical cleaning i.e. without de-inking. They comprise products like testliner, corrugating medium, board and cartonboard.
- Processes with mechanical and chemical unit processes i.e. with de-inking. They comprise products like newsprint, tissue, printing and copy paper, magazine papers and some grades of cartonboard.

The raw materials for RCF based paper production consist mainly of recovered paper, water, chemical additives, and energy in the form of steam and power. Large quantities of water are used as process water and cooling water. As processing aids and to improve the product properties (paper auxiliaries) various additives are applied during paper manufacturing. The environmental impact of recovered paper processing comprises basically emissions to water, solid waste (especially if wash de-inking is applied as e.g. in tissue mills) and atmospheric emissions. Emissions to the atmosphere are mainly related to energy generation by combustion of fossil fuels in power plants. Most recovered paper processing mills are integrated with paper manufacture. Therefore, the emission levels associated with the use of BAT are given for integrated mills. A big part of the techniques to be considered in the determination of BAT refers to the reduction of emissions to water.

Best available techniques for recovered paper processing mills are considered to be:

- 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;
- Generation of clarified water for de-inking plants (flotation);
- Installation of an equalization basin and primary treatment;
- Biological effluent treatment: An effective option for de-inked grades and depending on the conditions also for non-de-inked grades are aerobic biological treatment and in some cases also flocculation and chemical precipitation. Mechanical treatment with subsequent anaerobic-aerobic biological treatment is the preferable option for non-de-inked grades. These mills usually have to treat more concentrated wastewater because of higher degree of water circuit closure.
- Partial recycling of treated water after biological treatment. The possible degree of water recycling is depending on the specific paper grades produced. For non-de-inked paper grades this technique is BAT. However, the advantages and drawbacks need to be carefully investigated and will usually require additional polishing (tertiary treatment).
- Treating internal water circuits.

For integrated recovered paper mills, the emission levels associated with the use of a suitable combination of best available techniques are tabulated in Table 4.1.

Table 4.1 Emission levels for integrated recovered paper mills

	Flow m ³ /t	COD kg/t	BOD kg/t	TSS kg/t	Total N kg/t	Total P kg/t	AOX kg/t
Integrated RCF paper mills without de- inking	< 7	0.5-1.5	<0.05- 0.15	0.05- 0.15	0.02-0.05	0.002- 0.005	<0.005
Integrated RCF paper mills with de-inking	8-15	2-4	<0.05- 0.2	0.1-0.3	0.05-0.1	0.005- 0.01	<0.005
RCF based tissue mills	8-25	2-4	<0.05- 0.5	0.1-0.4	0.05-0.25	0.005- 0.015	<0.005

The BAT emission levels refer to yearly averages and are presented separately for processes with and without de-inking. The waste water flow is based on the assumption that cooling water and other clean water are discharged separately. The values refer to integrated mills i.e. recovered paper processing and papermaking is carried out at the same site.

Common treatment of wastewater from a RCF paper mill or a consortium of RCF paper mills in the municipal wastewater treatment plant is also considered as BAT when the common treatment system is appropriate for dealing with paper mill effluents. The removal efficiencies of the common waste water treatment system should be calculated and the comparable removal efficiencies or concentrations of releases established before considering this option as BAT.

Air emissions in RCF based paper mills are mainly related to plants installed for the production of heat and in some cases for co-generation of electricity. Saving of energy corresponds therefore with reduction of air emissions. The power plants are usually standard boilers

and can be treated like any other power plants. To decrease energy consumption and air emission the following measures are considered as BAT:

- Co-generation of heat and power,
- Improving existing boilers,
- Use of less energy consuming equipment when equipment is replaced.

Best available techniques for reducing waste are to minimize the generation of solid waste and recover, recycle and re-use these materials, wherever practicable. Separate collection and intermediate storage of waste fractions at source can be beneficial to meet this aim. When the collected waste is not re-usable in the process external utilization of residuals/waste as substitutes or incineration of organic materials in suitably designed boilers with energy recovery is considered as BAT. Reduction of solid waste can be achieved by optimizing the fiber recovery by upgrading of stock preparation plants, optimization of the amount of cleaning stages in the stock preparation, application of dissolved air flotation as in-line treatment of water-loops to recover fibers and fillers and to clarify process water. A balance between cleanliness of stock, fiber losses and energy requirements and costs has to be found and it usually depends on the paper grades. The reduction of the amount of solid waste to be landfilled is BAT. This can be achieved by efficient reject and sludge handling on-site (de-watering) to enhance dry solids content and subsequent incineration of sludge and rejects with energy recovery. Produced ash can be used as raw material in the building materials industry. Different options for incineration of rejects and sludge are available. The applicability is limited by the size of the mill and to a certain extent by the fuel used for generation of steam and power respectively.

Energy efficient recovered paper mills consume process heat and power as follows:

- Integrated non-de-inked RCF paper mills (e.g. testliner, fluting): 6 - 6.5 GJ/t process heat and 0.7 - 0.8 MWh/t of power;
- Integrated tissue mills with DIP plant: 7 - 12 GJ/t process heat and 1.2 - 1.4 MWh/t of power;
- Integrated newsprint or printing and writing paper mills: 4 - 6.5 GJ/t process heat and 1 - 1.5 MWh/t of power.

4.3.3 BATs for papermaking and related processes

Paper is made from fibers, water and chemical additives. Furthermore, a lot of energy is needed to drive the whole process. Electric power is mainly consumed for the operation of various motor drives and for refining in stock preparation. Process heat is mainly used for heating of water, other liquors, and air, evaporating water in the dryer section of the paper machine, and conversion of steam into electric power (in case of co-generation). Large quantities of water are used as process water and cooling water. As processing aids and to improve the product properties (paper auxiliaries) various additives may be applied during paper manufacturing.

The environmental issues of paper mills are dominated by emissions to water and by the consumption of energy and chemicals. Solid waste is also generated. Atmospheric emissions are mainly related to energy generation by combustion of fossil fuels in power plants.

Best available techniques for reducing emissions to water are

- Minimizing water usage for different paper grades by increased recycling of process waters and water management;

- Control of potential disadvantages of closing up the water systems;
- Construction of a balanced white water, (clear) filtrate and broke storage system and use of constructions, design and machinery with reduced water consumption when practicable. This is normally when machinery or components are replaced or at rebuilds;
- Application of measures to reduce frequency and effects of accidental discharge;
- Collection and reuse of clean cooling and sealing waters or separate discharge;
- Separate pre-treatment of coating wastewaters;
- Substitution of potentially harmful substances by use of less harmful alternatives;
- Effluent treatment of wastewater by installation of an equalization basin;
- Primary treatment, secondary biological, and/or in some cases, secondary chemical precipitation or flocculation of wastewater. When only chemical treatment is applied the discharges of COD will be somewhat higher but mainly made up of easily degradable matter.

For non-integrated paper mills the emissions levels that are associated with the use of BAT are presented in Table 4.2 for uncoated and coated fine paper and tissue separately. However, the differences between the paper grades are not very distinct.

The BAT emission levels refer to yearly averages and exclude the contribution of pulp manufacturing. Although these values refer to non-integrated mills they can also be used to approximate emissions caused by papermaking units in integrated mills. The waste water flow is based

on the assumption that cooling water and other clean water are discharged separately.

Common treatment of wastewater from a paper mill or a consortium of paper mills in the municipal wastewater treatment plant is also considered as BAT when the common treatment system is appropriate for dealing with paper mill effluents. The removal efficiencies of the common wastewater treatment system should be calculated and the comparable removal efficiencies or concentrations of releases established before considering this option as BAT.

Table 4.2. Emission levels for non-integrated paper mills with respect to paper grades

Parameters	Units	Uncoated fine paper	Coated fine paper	Tissue
BOD	kg/tones of paper	0.15 – 0.25	0.15 – 0.25	0.15 – 0.4
COD	kg/tones of paper	0.5 – 2	0.5 – 1.5	0.4 – 1.5
TSS	kg/tones of paper	0.2 – 0.4	0.2 – 0.4	0.2 – 0.4
AOX	kg/tones of paper	<0.005	<0.005	<0.01
Total P	kg/tones of paper	0.003 – 0.01	0.003 – 0.01	0.003 – 0.015
Total N	kg/tones of paper	0.05 – 0.2	0.05 – 0.2	0.05 – 0.25
Flow	m ³ /tones of paper	10 - 15	10 - 15	10 - 25

Air emissions from non-integrated paper mills are mainly related to steam boilers and power plants. These plants are generally standard boilers and do not differ from any other combustion plants. It is assumed that they are regulated like any other auxiliary boiler of the same capacity.

BAT concerning solid waste is the minimization the generation of solid waste and recovery, reuse and re-cycle of re-usable materials as far as possible. Separate collection of waste fractions at source and intermediate storage of residuals/waste can be beneficial to allow for a greater proportion to be reused or recycled rather than landfilled. Reduction of fiber and filler losses, the application of ultra-filtration for coating wastewater recovery (only for coated grades), efficient dewatering of the residues and sludge to high dry solids are further available techniques. BAT is the reduction of the amount of waste to be landfilled by identification of possibilities for recovery operations and - if feasible - utilization of waste for material recycling or incineration with energy recovery.

In general, in this sector, BAT is considered to be the use of available energy efficient technologies. A lot of options for energy saving in many stages within the manufacturing process are available. Usually these measures are linked with investments to replace, rebuild or upgrade process equipment. It should be noticed that energy saving measures are mostly not applied only for energy saving. Production efficiency, improvement of product quality and reduction of overall costs is the most important basis for investments. Energy savings can be achieved by implementation of a system for monitoring energy usage and performance, more effective dewatering of the paper web in the press section of the paper machine by using wide nip (shoe) pressing technologies and use of other energy efficient technologies as e.g. high

consistency slushing, energy efficient refining, twin wire forming, optimized vacuum systems, speed adjustable drives for fans and pumps, high efficiency electric motors, well sized electric motors, steam condensate recovery, increasing size press solids or exhaust air heat recovery systems. A reduction of direct use of steam can be achieved by careful process integration by using pinch analysis.

Energy efficient non-integrated paper mills consume heat and power as follows:

- Non-integrated uncoated fine paper mills have a process heat demand of 7 - 7.5 GJ/t and a power demand of 0.6 - 0.7 MWh/t;
- Non-integrated coated fine paper mills have a process heat demand of 7 - 8 GJ/t and a power demand of 0.7 - 0.9 MWh/t;
- Non-integrated tissue mills based on virgin fibre have a process heat demand of 5.5 - 7.5 GJ/t and a power demand of 0.6 - 1.1 MWh/t.

4.3.4 BAT for auxiliary boilers

Depending on the actual energy balance of the given pulp or paper mill, the type of external fuels used and the fate of possible bio-fuels as bark and wood-waste there are atmospheric emissions from auxiliary boilers to consider. Pulp and paper mills manufacturing pulp from virgin fibers are normally operating bark boilers. For non-integrated paper mills and RCF paper mills air emissions are mainly related to steam boilers and/or power plants. These plants are generally standard boilers and do not differ from any other combustion plant. It is assumed

that they are regulated like any other installation of the same capacity. BATs are:

- Application of cogeneration of heat and power if the heat/power-ratio allows it
- Use of renewable sources as fuel such as wood or wood waste, if generated, to reduce the emissions of fossil CO₂
- Control of NO_x emissions from auxiliary boilers by controlling the firing conditions, and installation of low-NO_x burners
- Reducing SO₂ emissions by using bark, gas or low sulfur fuels or controlling S emissions
- In auxiliary boilers burning solid fuels filters are used for the removal of dust.

4.3.5 BATs for the use of chemicals and additives

In the pulp and paper industry a large number of chemicals are used depending on the paper grade produced, the process design and operation and the product qualities to be achieved. On the one hand process chemicals for the production of pulp are required, on the other hand chemical additives and auxiliaries are applied in paper production. Chemical additives are used to give paper various characteristics while chemical auxiliaries are used to increase efficiency and reduce disruption of the production process.

For chemical usage the availability of a database for all used chemicals and additives and the application of the principle of substitution is considered as BAT. That means that less hazardous products are used when available. Measures to avoid accidental discharges to soil and water from handling and storage of chemicals are applied.

4.4 Debates On IPPC And Expected Future Work

Environmental regulation is challenging, especially in the EU that is comprised of so different Member States. It is not easy to improve the design of environmental permitting in such a way that it would be a substantial driver for eco-efficiency throughout Europe. Semi-binding standards could be considered instead of a completely integrated and flexible approach, but finding an appropriate level of performance would be extremely difficult. Due to large differences in environmental performance of industrial installations across EU, such level may have to be selected, that standards would not drive adoption of eco-efficient practices in countries where environmental issues have traditionally had higher priority. Strengthening in the role of the BREF could however be considered.

Environmental permits do not necessarily have to act as a driver for eco-efficiency of the majority of industrial installations. They can be used as safety net that ensures a certain level of performance, if other policy instruments are used successfully to drive environmental performance in more proactive ways (Honkasalo, 2003).

IPPC Directive is expected to increase competitiveness through savings in resources use. But if substantial investments are required to be made in techniques that have a long payback or no payback at all, the competitiveness could be altered (Honkasalo, 2003).

Studies show that plants that have already adopted BAT and achieve a good environmental performance are viable in the long run. However, in many cases BAT plants have particular characteristics; they tend to be large, already strongly competitive, growing, endowed with quality skills and undertake an above average input of R&D. These advantages influence the cost of investment in, and compliance with,

BAT. Therefore the impact of BAT on industry competitiveness depends on how it is implemented. Present experiences on BAT implementations show that; sample plants with a strong environmental performance are able to use this as a competitive strength (IPTS, 2001).

On the other hand, results of different studies indicate that the implementation of the BAT principle of the IPPC directive will reduce emissions but at the risk of not taking sufficiently account of economic efficiency. This implies that emission reduction could be achieved at lower costs, or alternatively that emissions could be further reduced at the same costs (Larsson and Telle, 2005).

BAT experiences in pulp and paper industry show that in general; the mills that have implemented BATs have stronger economic performance, higher labor productivity and sales per head values, lower per tone costs, increased capacity and growth rates. Also, strong environmentally performing mills reported a derived competitive advantage. On the other hand it is reported that, end-of-pipe techniques have a negative impact on profitability (IPTS, 2001).

Regarding these debates, at the moment, the IPPC Directive is reviewed while not altering the fundamental principles, objectives and ambition of the present Directive. The core objective of the review is to encourage industry to go beyond regulatory compliance. Also it is stated that the EU is thinking of experimenting with a number of concepts and changing the way IPPC is developed to cover a number of issues (Dredge, 2005):

- The expansion of BAT beyond installations (supply chain, lifecycle issues)
- How to expand the role of Environmental Management Systems and voluntary agreements in IPPC
- The integration of IPPC and other EU directives
- How to develop incentives for operators to go beyond BAT

- The use of multiple site permits (bubble or co-ordinate permits)
- How to handle split sites (one site with multiple operators & permits).

5. CLEANER PRODUCTION CASES

In this section of the study, cleaner production cases in pulp and paper industry from different countries will be examined. Economic and environmental benefits of cleaner production applications are emphasized.

As mentioned in previous sections of the study, cleaner production options can be implemented as changes in raw materials, changes in technologies, good operating practices, recycling and reuse and product changes. In most cases, more than one cleaner production (CP) principle is possible. The following cases are a compilation of different CP opportunities in different countries conducted in the last 15 years but still applicable especially in developing countries. Some of them are very common and well-known practices and some are not. Cases are introduced with the “Background” sections, cleaner production opportunities are identified in the “Application” sections and the results of the cases are given in the “Economic and Environmental Aspects” sections. Most widely used data base for cleaner production cases is The International Cleaner Production Information Clearinghouse (ICPIC) database developed by the UNEP for the effective promotion of Cleaner Production worldwide. Some of the cases represented here can be reviewed in the cited references and also in this ICPIC database. When the case studies were reviewed in the literature, it is found out that for the implementation of environmentally sound technologies; the most important reason for the pulp and paper firms operating in free market economies, like Brazil and India, is the regulatory pressure whereas the most important reason for the pulp and paper firms operating in socialist economies, like China and Vietnam, is the reduction in the costs of energy and raw material. Interestingly, one should note that cost

reductions are an important driver for firms in Brazil and almost the second most important driver for firms in India (Luken, 2004).

5.1 Technology Change Principle

A. Bleaching with ozone, oxygen and peroxide

Background: The paper industry is searching for a way to get rid of the chlorinated products for bleaching the chemical pulp. There has been developed a way to bleach Kraft pulps without chlorinated derivatives, ensuring a whiteness of 86.5%. This case is from a French mill, conducted in 1992 and undergone a technical review in 1998 (DPPEA, 1992).

Application: During the Kraft pulping, the lignin is dissolved under the action of chemicals (soda), temperature and pressure. The raw fibers obtained are bleached by means of oxidizing agents. The plant was using a standard process with chlorine, hypochlorite and chlorine dioxide, generating organochlorinated substances in the effluents and the pulp. The new bleaching technique uses neither chlorine nor chlorinated derivatives and uses ozone, oxygen and peroxide. After standard wood heating, the new process is as follows:

- 1) **Lignin removal using oxygen:** Washing the filter, injection of oxygen into the mixing chamber and reaction, washing the filter.
- 2) **Chelating phase:** Treatment using sulfuric acid and a chelating agent.
- 3) **High consistency ozone phase:** Increase in the consistency of up to 35 % on filter press, ozonation.

- 4) **Peroxide-oxygen phase:** Soda injection: injection of steam at 80°C, introduction of peroxide, injection of oxygen and reaction in a tower.
- 5) **High consistency peroxide phase:** Increase in the consistency of up to 40 % on filter press, treatment with peroxide.

Economic and Environmental Aspects:

- Total suppression of chlorine in the process. Decrease by 97 % in the effluent color.
- Reduction in the malodorous discharges into the air from lower sulfide ratio of the pulp.
- Whiteness of the Kraft pulp without chlorine is equivalent with the processes using chlorine.
- All the effluents, free from chlorine, can be reused in a recovery boiler.
- Possibility of building a plant with closed water circuit.

B. Pinch analysis in a pulp and paper mill

Background: This case study is conducted in Canada (NRC, 2003) and illustrates the benefits of a retrofit study in the frame of pinch technology in a thermo-mechanical paper mill. The flowchart of the process before and after heat integration and composite curves and temperature versus heat load graphs are given in Appendix C.

Application: It was planned to increase production by 10% in the upcoming year. However, the steam plant has already reached its full

capacity with present needs. The same problem occurs with the capacity of the cooling towers for the effluent, which is already short during the peak summer period. In order to increase capacity without spending money on new boilers and cooling towers, management wants to use energy savings to reduce the mill's cooling and heating requirements. At the same time, the mill wants to reduce its greenhouse gas emissions in a profitable way. Management requires a maximum average payback period of 12 months for the combination of projects, and a maximum payback period of 24 months on each individual project. To reach these goals, Pinch Analysis was selected to minimize the process steam usage and to reduce the effluent temperature to as close to the optimum operating temperature of the treatment plant as possible. The first step consists in analyzing the process flow-sheet and its mass and energy balance data. This allows the extraction of the basic data required for the Pinch Analysis. Data of the process streams that are in concern is tabulated in Table 5.1.

Table 5.1. Process stream data for pinch analysis

No	Description	Type	T _{initial} (°C)	T _{target} (°C)	Q (kW)	h (kW/ m ² °C)	CP (kW/ °C)
1	Chip cleaners effluent	Hot	80	35	7500	3.0	300
2	Paper machine hot water	Cold	25	60	-9800	3.5	280
3	Make-up water to boilers	Cold	25	90	-5525	3.7	85
4	Water from TMP disk filters' showers	Cold	85	85	-5000	3.1	250
5	Reboiler condensate	Hot	140	35	9776	2.9	93

Using the data given in Table 5.1, the hot and cold composite curves are drawn. The minimum cold and hot utility targets and the energy recovery load are related to the position of the two composite curves, relative to one another. This positioning is characterized by the minimum allowable temperature difference, $\Delta T_{\min}$ between both curves. Consequently, the minimum utility targets for process heating and cooling are directly related to the choice of $\Delta T_{\min}$. For this case $\Delta T_{\min}$ is selected to be 12 °C. The composite curves are also used to estimate the minimum capital costs (capital cost target) required for the purchase and installation of new heat exchangers that will bring the utility loads to their minimum values. This cost evaluation has two main components: the minimum number of heat exchangers to be installed and the total minimum heat exchange area required by all heat exchangers in the network. For this case, the minimum number of heat exchangers required to reach the cold and hot utility targets (N) is 3, and the minimum total heat exchange area is 549 m². After the determination of $\Delta T_{\min}$, the hot and cold pinch points are observed from the composite curve graph (60°C and 48°C for this case respectively) and then the final design procedure is applied to the system.

Economic and Environmental Aspects: Table 5.2 summarizes the data of the system and energy savings before and after the retrofit study. The new design also generates fresh water savings by eliminating the reboiler condensate dilution, originally encountered in the scrubber. This contributes to a reduction of the effluent volume by 31%. Furthermore, it is important to emphasize that, in addition to reducing energy costs related to steam production, these projects also eliminate the capital costs that would have been associated with increasing boiler and cooling tower capacity.

Table 5.2 Process system data before and after the retrofit study

Parameter	After Retrofit	Before Retrofit
Steam usage (kW)	4,694	20,325
Energy savings (kW)	15,631	-
Total exchange area (m ²)	590	0
Number of exchangers	3	0
Effluent temperature (°C)	40.3	61
Energy savings (k\$/year)	1,407	-
Capital costs (k\$)	1,397	-
Payback period (months)	11.8	-

C. Process and equipment modification

Background: M/S Ashoka Pulp and Paper Mills is an agro-residue based pulp and paper mill producing unbleached semi-Kraft paper. This case was conducted in India in 1993 (CBI, 1993). The average production of the mill is 36 tons per day. Excessive paper breakage often occurred during the final stage of the paper making process. The causes included:

- Pressure fluctuations at the edge cutting nozzles due to variations in levels in the water storage tank;
- Variations in pulp consistency;
- Excessive fines in pulp due to inefficient dusting of raw material;
- A deteriorating quality of press rolls;
- Use of single felts, resulting in a high shear force.

The first two items were due to improper process control, and the rest due to obsolete process technology.

Application: The problems were solved by a combination of process modification, equipment modification, and new technology:

- A separate water storage tank and pump were installed to ensure a constant water level, and thus constant water pressure at the edge cutting nozzles.
 - An additional smaller water pipeline was installed at the dilution point, along with a consistency indicator for precise consistency control at the inlet of the paper machine.
 - New technology, comprising mechanical dusting of raw material, was adopted to reduce fines in the pulp.
-
- Mild steel rolls, which have a smoother surface, replaced the existing ebonite press rolls and the single felt system was replaced by a double felt system.

Economic and Environmental Aspects: A total investment of US\$ 25,000 was done and this investment brought US\$ 133,980 annual savings and the investment had a payback period of less than 3 months.

D. Equipment change and process optimization

Background: This case study was conducted in Turkey in İpek Kağıt Paper Mill as a retrofit project in 2003. The goal of the project was to reduce natural gas, steam and electricity consumption in the dryer. It was aimed to minimize process shut-downs and increase production output with the improvements in the boiler room (İpek Kağıt Sanayi Ticaret A.Ş., 2003).

Application: With the support of top-management, production and maintenance engineers collaborate and finalized the project with in 9 months. The present old-fashioned, manually and mechanically controlled burner is replaced with a new one. Also the steam load was optimized between the rolls and the steam usage was increased while natural gas consumption is decreased for optimal cost-efficiency ratio.

Economic and Environmental Aspects: Efficiency in the boiler room was increased and 60% reduction in CO emissions was achieved. A total of US\$ 360,000 annual savings were obtained due to savings in energy and improved production outputs. The investment required for this case was only US\$ 20,000 and pay back period was only 20 days.

5.2 Recycling and Reuse Principle

A. Recycling, substitution and fiber recovery

Background: A mill with an annual production capacity of 790,000 tons of short fiber pulp, and 254,000 tons writing and printing paper tried to minimize the environmental impact of its activities through the use of cleaner production technology. This case is from an Indonesian mill (CBI, 1993).

Application: Following studies were conducted in the mill:

- Using a heat recovery system to recover heat from the digesters before the pulp is discharged now provides more than 11 m³ of wash water at a temperature of 70°C per ton of pulp.

- Using oxygen rather than bleaching chemicals to reduce the lignin in the pulp has lowered the chemical and biological oxygen demand of the effluent.
- Recycling the cooking chemical provides power for cooking, pulp drying and paper-making, and has reduced the chemical oxygen demand of the effluent from 14,000 to 1,400 ppm.
- Recycling the water from the pulp drying machine using a cascade system has reduced the water consumption by 23% per ton of pulp.
- A fiber recovery system is used to recover good fiber from reject pulp, and is saving 40 tons of pulp per day, worth US\$ 7000 a day.

Economic and Environmental Aspects: The studies resulted with energy savings, reduction in use of clean water, raw material savings and less effluent needs treatment. The total investment cost of the environmental protection system was about US\$ 42 million. The system includes the treatment of solid, liquid and gaseous wastes. A further US\$ 1.8 million was invested in a fiber recovery system.

B. Water collection

Background: Linh Huan Paper Company is a medium sized pulp and paper mill, having an installed capacity of 2000 ton/year tissue paper and 5000 ton/year ceremonial joss paper using waste paper and bamboo waste as raw materials. Of late, the company has transferred the joss paper production section to another company, therefore, this case deals only with tissue paper production. This case was conducted in Vietnam in 1999 (Linh Xuan Paper Company, 1999).

Application: A cleaner production team with 7 members was established and major attention was paid to reduce the consumption of water, bleaching chemicals, waste paper, fuel and electrical energy, as well as proper control on consistent paperweight. After the detailed cleaner production assessment and data compilation, 34 viable cleaner production measures were selected for implementation. Cleaner production measures can be categorized into following clusters:

- Collection of white water, cleaning water, steam condensates and escaped fiber for reuse/recycle in the process
- Replacement of old equipment, paper machine, and boiler with high efficiency equipment
- Improved stock cleaning to improve paper quality and enable the production of low weight twin ply tissue
- Improved moisture withdrawal from paper to reduce energy consumption and increased production by increasing paper machine speed
- Power factor correction by installing inverter and sensors in major power consuming areas

Economic and Environmental Aspects: A total investment of US\$ 55,000 was done that brought US\$ 100,000 annual savings where pay back was less than 6 months. Waste water volume was reduced 45% and organic pollution load was reduced 35%. Levels of 20% reduction in gaseous emissions and 30% reduction in solid waste generation are achieved. Also production capacity was increased and product quality was improved.

C. Closed water-loops

Background: This case study was conducted in a very small family-run paper mill in UK (Clayton et al., 1999). The mill has 25 employees and has a annual production capacity of 3,000,000 tons of low-quality paperboard made from waste paper and corrugated cardboard. There was river next to the mill that is used as water source and also a sink for effluents. The effluent was rich in paper fibers, which exceeds the regulatory TSS and BOD limits. It was expensive for a small-scale mill to construct a treatment plant, therefore the company decided to increase waste water recycling.

Application: Company installed a filter that screens large fibers and this allowed recycling of water for the first time and major reductions in effluent charges was obtained. In addition to the filter, a balancing tank and a system of pipes and pumps were installed in the system, and by this way all wastewater was started to be recycled directly into the pulping section. The mill has become a closed loop, with no regular discharges. Water loss due to the paper drying process is replaced with fresh water from the river when required. Only occasionally a small amount of excess recycled water goes from the balancing tank to the sewer system. The balancing tank has to be drained twice a year to prevent biological activity in the sludge.

Economic and Environmental Aspects: The total investment cost for the balancing tank and piping system was UK £ 4000. The company cut its sewage charges substantially and reduced water use.

5.3 Good Operating Practices Principle

A. Water and ink waste reduction

Background: The company is a cardboard box manufacturer and printer. Presses must be cleaned every time the ink is changed. The bulk of the ink contained in the bins and on other parts of the press is poured back into the ink container. The remaining ink was washed off with water-soaked rags and the wastewater was put in 55-gallon drums and, before the ink change, taken away by a hazardous waste contractor at US\$ 100 per drum. Before implementation of the waste reduction program the company generated 10 drums of hazardous waste a week, now it generates one to two drums a week of non-hazardous waste. This case is from a USA mill (DPPEA, 1992).

Application: Company decided that the reduction of the volume of water used in the cleaning process could be achieved by training the workers to use the least amount of water possible. The company has trained its employees in "good housekeeping" practices and significantly reduced ink wastes and wastewater generated when cleaning the printing presses. The improved washing practices include draining and scraping as much ink as possible before washing and minimizing the amount of water used. Most of the ink wash water is now used to dilute concentrated virgin black ink. The new washing procedures include draining as much ink as possible back into the containers and thorough scraping of excess ink off the press parts before any water is added, and then using as little water as possible. In addition to reducing the volume of wash water used, the company asked its supplier to deliver black ink with 10% reduced water content. Wastewater is added to the black ink with no apparent effect on

the color quality of the ink. The wastewater can also be added to other colors, such as gray, in smaller amounts than when added to black ink.

Economic and Environmental Aspects: Modifying the press cleanup procedure reduced the solids in spent wash water from more than 30%. The volume of water used also has decreased by 35%. By reusing most of the wash water, the amount of waste, which had to be disposed, has decreased from ten to two 55-gallon drums per week. The decrease in wash water and the reuse of ink wastewater have resulted in 90% savings in waste disposal as well as reduced costs for raw materials. The 55-gallon drums of waste cost approximately US\$ 100 each to dispose. Implementing the reuse of ink wastewater has reduced the yearly cost of waste disposal from about US\$ 52,000 to US\$ 5,200.

B. Reducing water use

Background: One of the largest companies in Jordan, which produces annually 30,000 tones of hygienic paper, decided to reduce water consumption to the minimum limits without affecting negatively the quality. This was done to reduce natural resources depletion to support the socio-economic development continuation and to prevent environmental pollution resulted from excessive water consumption as wastewater, also to reduce the cost as a result of lower water consumption. This case is from a mill in Jordan (Al-Keena Hygienic Paper Mill Co. Ltd, 2004).

Application: The first stage was public awareness program to inform and educate people in the factory about the seriousness of water situation in Jordan, in addition to company's plan of water consumption reduction

leading involvement for all staff in the plant. The second stage in the plan was to look at water ingress to the factory, the places of water addition and the amounts of addition and to measure the actual consumption in order to determine and study the potential of water consumption reduction. At this stage the company used consulting firms from Jordan and Europe to assist in the study and in projects implementation. After the project completed the water consumption was significantly decreased. Treated wastewater started to be used for irrigation purposes in a farm around the factory. In addition to that on the same location of the company there are two sister companies but the wastewater from these two companies is not suitable for irrigation purposes due to high concentration of some chemical compounds. Another plan was proposed to mix the wastewater from the three companies to reduce the concentration of chemical compounds; eventually the resulted water was suitable for irrigation and high savings were achieved for those two companies. Also, in order to improve treated wastewater management, the company invested in purchasing and renting lands around the factory for agricultural purposes. Now they produce 12 ton of olive oil at value of 4000 JOD, and 14 ton of grass used as animal foods at value of 2000 JOD. The net profit from this agricultural project was around 1000 JOD. Moreover the actual profit than money wise was the improvement of environment around the factory, the company is now located in the middle of green land, produces food, and improves the environment.

Economic and Environmental Aspects: The total water consumption per day was 800 cubic meters; the expected reduction was 30%, at the end of this plan, the actual reduction exceeds 43%. The total investment was around JOD 400,000 (including control valves, instruments, equipment, consultancy) and the annual savings were estimated to be JOD 50,000. The reduction in use of fresh water and the new wastewater

management system improved also the energy usage in the factory. The company reduced the amount of gases emissions by 5554 ton per year and reduced the consumption of fresh water per ton of product from 11m^3 to 6m^3 .

6. RESULTS AND DISCUSSION

In this section of the study, results derived from the literature investigations, surveys and case studies are presented, and discussions are made where appropriate. This section follows the structure of the whole text while results and discussions are clustered according to the previous sections.

Pulp and Paper Industry

Pulp and paper industry is an important sector in manufacturing industry due to the substantial and essential role of paper in our lives. Although there is a trend to replace some paper products with plastic or electronic media, demand for paper products is increasing. New specialty paper grades widen new markets especially in developed countries. Per capita consumption of paper is increasing in both developed and developing countries and the great difference between two consumption levels is an indicator of the positive growth trend of the industry. This sector is capital intensive and this brings the fact that it is difficult to enter the market as a new player, or growing in the market by establishing new mills. The trend is having transnational acquisitions and improving the capacities of existing mills. Although specialty grades are becoming more and more important, high investment and operating costs bring the necessity of bulk production. Recycling and processing recycled fibers are gaining importance, especially in countries that are lack of natural cellulose sources and in addition to that plantation is now considered to be the kind of first unit operation for pulp and paper mills.

Pulp and paper industry consumes a significant amount of natural sources, raw materials and energy. Due to this fact, the amount of wastes generated and the environmental impact of the sector become important.

It is stated that this sector is in the third place for generating water pollution and in the fifth place for generating air pollution among the manufacturing sectors. It is a global average that pollution prevention costs account for 2.4% of the total production cost, which is a significant fraction. These facts make this sector a key industry for focusing efforts to make the industry more sustainable.

Capacity and production figures as well as per capita consumption figures show that Turkish pulp and paper industry is growing. Nevertheless, the sector is losing its competitiveness power to Western companies. The main reason for this undesired fact is that production technology is very old; bringing inefficiency, high labor costs and low machine speeds. Another problem is that all forestry land is state owned and private sector is unable to use natural cellulose as a raw material. Some companies started plantation, but these small volume initiations do not solve the problem of high cost production inputs due to imported cellulose. On the other hand, waste paper recycling rates should be increased to a level of more than 50% to decrease raw material costs in the sector. Energy, specifically electricity is still very expensive for Turkish producers when compared to their Western competitors. Also the government is not in favor of cogeneration plants. All these cost related issues decrease the competitiveness power of Turkish companies.

Statistics foresee that pulp and paper industry will become more important in the profile of the Turkish industry. For this reason, cleaner technologies should be used for new paper mill designs and start-ups. This will reduce the raw material and natural resource usage and increase the efficiency and by this way, Turkish firms will be able to compete with foreign firms. Also the emission values should meet the EU Environmental Regulations, otherwise export problems will occur in this sector. Eco-labeling can be a trade barrier for Turkish companies in the future, so companies should follow this issue.

Survey results show that water consumption levels vary a lot from company to company. But average values are not very far from European companies. When it comes to environmental performance of Turkish pulp and paper companies, it is seen that emission values are very high when compared to companies in Europe. Especially there are significant differences in emissions to water. This fact is due to old technology and unawareness of environmentally friendly technologies. Many companies even do not have a water treatment facility. Turkish regulatory values are also very high and regulatory system is not strict.

Answers to the non-technical questions in the survey bring a conflict between the answers on sheets and the reality. All of the responders state that they believe in cooperation with universities about the application of cleaner technologies. But none of the companies wanted to collaborate for conducting a case study. Actually this is a major problem in the Turkish industry that companies do not cooperate with each other or with third bodies under the cover of secrecy policies. But in developed countries, companies try to identify and solve a problem together and benefit from the solution as the whole sector or even as a country. But in Turkey, there is an exaggerated level of confidentiality that prevents knowledge exchange and hinders development of private sector. It is believed that, industry associations should play a key role about performing joint projects in cleaner production technologies and promote knowledge exchange and information dissemination between companies. Private sector should also be eager to develop projects with state organizations and universities for the R&D phase of the cleaner production technologies.

When the competition in pulp and paper industry is investigated, it is believed that companies that are too small, too old, lacking of raw materials to improve their capacity, not able to buy raw materials at about average costs, producing small scale paper grades and that are not

performing well in environmental performance will face difficulties in sustaining their competitiveness power in the future.

Sustainable Development

Although the concept of sustainable development has a history of more than 25 years, the real understanding of what is behind this concept has started in mid 1990s. The global, regional and local environmental movements were focusing on pollution caused by manufacturing industry and activists desired concrete steps for the reduction of negative environmental impact of manufacturing companies on environment. This was considered as a new but different market threat for companies and managers started to think of new ways, namely more sustainable ways, of producing goods. It became inevitable to achieve sustainable production processes due to international environmental issues such as global warming. In today's business environment; responsible entrepreneurship and corporate social responsibility are the hottest topics.

Greatest importance to the achievement of sustainable business activity is the need to shift management thinking so that the environment is placed high on the business agenda and environmental concerns are integrated into company.

Today, there are many terms used for defining the activities that help business to reduce negative environmental impact. These include; pollution prevention, eco-efficiency, cleaner production technologies, environmentally sound technologies, etc. All have different definitions, different systematic approaches but their goal is the same and mostly they somehow cover each other. Here, the most important point is that there is shift from end-of-pipe solutions to in-source reduction solutions, where environmental concerns are taken as constraints in the R&D phases of designing, developing or establishing new manufacturing

processes in the latter. To become more environmental friendly, a company may invest in clean technologies or pollution control technologies. The environmental and economic impacts of these two types of technologies differ. Pollution control technologies are distinct stand-alone units that are added to the production process. They capture and/or treat emissions. Clean technologies are technologies where environmental considerations have been taken into account in their design or application to reduce the environmental impacts. The possibilities to solve environmental problems with pollution control technologies are limited. Clean technologies address environmental impacts at source, whereas pollution control technologies only treat emissions that have already been created. Costs and benefits of clean technology and pollution control technology are realized at different times. In long term, the adoption of clean technology is more economically beneficial due to related savings but the initial investment may however be larger. Pollution control technologies tend to look more attractive if the investment is assessed in short term. Both clean technologies and pollution control technologies are needed. Prevention of pollution at the source should be a priority, but it is not always possible. Pollution control technologies are needed to complement clean technologies.

When case studies presented in this study are examined, it is seen that cases conducted 10-15 years ago, are still applicable. This means that there are always improvement options in every process and environmental performance improvement is a continuous process. A technology that is considered as old in one company can be a better alternative for another company.

In the past, most firms addressed specific pollution issues rather than today's strategically implemented clean technology investments to create a source of competitive advantage. Like in all business cultures,

investments concerning environmental performance are always considered to be done to comply with regulations instead of gaining competitive advantage in Turkey. Turkish private sector should bear in mind that investment done for environmental performance improvements always bring economic benefits and improves competitiveness power of companies.

IPPC Directive

The IPPC Directive strives to call an increasing attention to the prevention of pollution at source. In the past, environmental regulation has had a major impact to environmental impacts of industry, but it has mostly driven the adoption of end-of-pipe technologies. If IPPC Directive manages to shift the focus to pollution prevention, there is a possibility that it yields also economic benefits for the industry.

When discussed in environmental aspects, IPPC supports the adoption of clean technology, because it mentions issues that cannot be solved at the end of pipe. For example, the use of less hazardous substances, low-waste technology and consumption and nature of raw materials are to be taken into consideration when determining BAT. So, it can be clearly stated that there is a link and interaction between cleaner production technologies and BATs.

There is a growing debate on IPPC Directive if it will hinder the competitiveness power of European firms. As a result of the investigated information; it can be stated that implementation of IPPC Directive will negatively impact some companies that have fragile competitiveness power. But when we talk in general, IPPC implementation will help companies to improve their product quality and production efficiency. In addition to those, companies will focus more on R&D activities and will cooperate with their suppliers and customers for the improvement of their

processes. They will deepen their knowledge about the production processes and will be kept up-to-date about technological progresses. Companies will achieve high environmental performance and as a result of that they will improve their image. On the other hand, results of different studies indicate that the implementation of the BAT principle of the IPPC directive will reduce emissions but at the risk of not taking sufficiently account of economic efficiency. This implies that emission reduction could be achieved at lower costs, or alternatively that emissions could be further reduced at the same costs.

To summarize, IPPC implementation will improve the competitiveness power of European companies while complying with European Commission's other environmental and economic strategies. But pulp and paper industry is very heterogeneous and impacts of BAT investments must be clearly identified before implementations.

BAT experiences in pulp and paper industry show that in general; the mills that have implemented BATs have stronger economic performance, higher labor productivity and sales per head values, lower per tone costs, increased capacity and growth rates. Also, strong environmentally performing mills reported a derived competitive advantage. On the other hand it is reported that, end-of-pipe techniques have a negative impact on profitability.

As Turkey is developing rapidly and expanding its industrial sector, it faces significant environmental problems. Turkey currently has in place a legal framework for the prevention of pollution and for the control and reduction of emissions and discharges (into air, water and soil) by industry. However, the subject of pollution is dealt with in a rather fragmented way in this legal framework. Another feature is that the licensing system in Turkey is based on the issuing of separate licenses for emissions and discharges into air, water and soil. Hence Turkey has no integrated system in line with EU regulations.

It is estimated that Turkish private sector needs a total investment of EUR 14 Billion to implement the necessities of the Directive. For this reason Turkish companies should seek alternative financing instruments to be able to invest in technologies that meet the Directive's criteria. Technology transfer may be a short-term solution for Turkey, but companies should focus on R&D and try to develop their own technologies to sustain technological advantage and high competitiveness power in the sector.

7. CONCLUSIONS

In this section, final conclusions on the thesis are given as short and clear remarks.

- There is a great growth potential of pulp and paper industry in Turkey and in the world.
- Recycled paper processing and plantation is gaining importance in the sector.
- Environmental impact of the sector is significant.
- Competitiveness power of Turkish pulp and paper companies is very low.
- Turkish pulp and paper companies have poor environmental performance.
- Eco-labeling can be a trade barrier for Turkish companies
- Turkish companies do not cooperate with each other or with third bodies under the cover of secrecy policies.
- Globally and also in Turkey, companies that are too small, too old, lacking of raw materials to improve their capacity, not able to buy raw materials at about average costs, producing small scale paper grades and that are not performing well in environmental performance will face difficulties in sustaining their competitiveness power in the future.
- Achieving sustainable production processes is inevitable due to international environmental issues.
- Pollution control technologies are distinct stand-alone units that are added to the production process.
- Clean technologies are technologies where environmental considerations have been taken into account in their design or application to reduce the environmental impacts.

- There are always improvement options in production processes and environmental performance improvement is a continuous process.
- A technology that is considered as old in one company can be a better alternative for another company.
- Investments concerning environmental performance are always considered to be done to comply with regulations instead of gaining competitive advantage.
- IPPC supports the adoption of clean technology, because it mentions issues that cannot be solved at the end of pipe.
- There is a link and interaction between cleaner production technologies and BATs.
- Implementation of IPPC Directive will negatively impact some companies that have fragile competitiveness power.
- In general, IPPC implementation will help companies to improve their product quality and production efficiency.
- IPPC implementation will improve the competitiveness power of European companies while complying with European Commission's other environmental and economic strategies. But pulp and paper industry is very heterogeneous and impacts of BAT investments must be clearly identified before implementations.
- Mills that have implemented BATs have stronger economic performance, higher labor productivity and sales per head values, lower per tone costs, increased capacity and growth rates.
- Turkey currently has in place a legal framework for the prevention of pollution and for the control and reduction of emissions and discharges.

- It is estimated that Turkish private sector needs a total investment of EUR 14 Billion to implement the necessities of the IPPC Directive.

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APPENDIX – A

In the following pages, there is the technical questionnaire -in Turkish- that was sent to companies.

KAĞIT ENDÜSTRİSİNDE ÇEVRESEL AÇIDAN DURUM TESPİT ANKETİ

Bu Anketi yanıtlayan firma yetkilisi/yetkilileri ile ilgili bilgiler: (Üretim Müdürü, Üretim Sorumlusu veya çevre konularında çalışma yapan kişi olabilir. Teknik anketin bu kişi tarafından doldurulması beklenmektedir.)

Adı ve Soyadı:

Unvanı:

Mesleği:

Ne kadar süredir işletmede çalışıyor:

Telefon numarası (Dahili numarası varsa lütfen yazın): (.....) Dahili:

E-posta adresi:

İletişim için e-posta kullanılmasını tercih eder misiniz? () Evet () Hayır

A. İŞLETME PROFİLİ

A1. İşletme Adı:.....

A2. Adres:.....

A3. Telefon: (.....) Faks: (.....)

A4. E-posta: Web Sitesi:.....

A5. Kuruluş Yılı:.....

A6. Çalışan Sayısı: Mavi Yaka (İşçi)..... Beyaz Yaka (İdari).....

A7. İşletme Statüsü: () Aile Şirketi () Çok Ortaklı () Kamu

() Yabancı Ortaklık (evet ise şirket ve ülke)

() Holding Kuruluşu (evet ise holding adı)

A8. Kapalı Alan m2 Açık Alan:..... m2

A9. İşletmenin bulunduğu yer: () Organize Sanayi Bölgesi

() Küçük Sanayi Sitesi

() Diğer

A10. İşletmenin sahip olduğu belge ve sertifikalar (ISO 9001, ISO 14001, Üçlü Sorumluluk,

Uluslararası Sertifikalar.....) Eğer başvuru varsa hangi aşamada olduğu belirtilebilir.

<u>Belge Adı</u>	<u>Alındığı Yer</u>	<u>Alınma Tarihi</u>
.....		
.....		
.....		

A11. Firmanın Faliyet Alanı:

Üretilen Ürünler / Ürün Grupları:.....

A12. Ürün bazında üretim kapasitesi (Lütfen yıllık olarak belirtiniz):

A13. İşletmenin üyesi bulunduğu ulusal ve uluslararası meslek üst kuruluşları (SKSV, OMÜD, TAPPI gibi)

B. ÜRETİM PROFİLİ

B1. Hammadde kaynakları, ara ürünler ve son ürünler (Lütfen işletmenize uyan tüm seçenekleri işaretleyiniz.)

ÜRÜNLER		() Kağıt Hamuru	() Kağıt	() Karton Kutu
HAMMADDE	() Ham selülozdan üretim yapıyor	() Odun	() Kağıt hamuru işletmede üretiliyor	() Kağıt işletmede üretiliyor
	() Saman	() Kağıt hamuru satın alınıyor	() Yurtiçinden	() Kağıt satın alınıyor
	() Atık Kağıt	() Yurtdışından	() Yurtiçinden	() Yurtdışından
	() Diğer			
	() İşlenmiş selüloz satın alınıyor			
	() Yurtiçinden			
	() Yurtdışından			

B2. Başlıca üretim adımlarını belirtiniz (Mümkünse üretim akış şemasını ekleyiniz):

1. 4. 7.

2. 5. 8.

3. 6. 9.

B3. Kullanılan başlıca yardımcı maddeler ve kimyasallar:

[illegible]

B4. SU KULLANIMI:

Suyun kaynağı: () Yer altı () Şehir Şebekesi () Irmak () Göl () Diğer:

Üretimde Kullanılan Su Miktarı [m^3 / gün]:

Suyun Birim maliyeti [TL / m^3]:

Birim ürün başına tüketilen su miktarı [m^3 su / ton kağıt] :

Çevrim suyu (üretimde yeniden kullanılan su, recycled / reused water) [m^3 /gün]:

B5. BUHAR KULLANIMI:

Buhar elde etme şekli: () Kendi Üretimi () Başka işletmeden satın alarak

Buhar kazanında kullanılan yakıt ve aylık tüketim miktarı:

() Fuel Oil

() Doğalgaz

() Elektrik

() Kömür : () Diğer.....

İşletmenin Buhar Üretim kapasitesi [basınç ve miktar olarak] :

Üretimde Kullanılan Buhar miktarı [ton / gün] :

Buhar çevrimindeki kayıp buhar miktarı [ton / gün] :

B6. ENERJİ KULLANIMI:

Elektrik: () Kendi Üretimi

Üretim Kapasitesi:

() Başka işletmeden satın alma Tedarik yeri ve miktarı:

() TEDAŞ

Kullanım Miktarı:

İşletmede **sadece üretimde** tüketilen günlük elektrik miktarı : [kWh]

İşletmede bazı üretim aşamalarında “puant saat” (elektriğin ucuz olduğu saatlerde çalışma)

uygulaması var mı?

() Evet

() Hayır

Birim ürün başına tüketilen enerji indeksi (Ör: # kW enerji / ton kağıt):

C. ATIKLAR:**C1. KATI ATIKLAR**

• Katı Atık Miktarı [ton / gün]:

• Katı atık içeriği :

• Bertaraf Şekli:

() Üretimde değerlendirme

() Yakma

() Başka işletmelere satma

() Diğer :

C2. GAZ ATIKLAR (EMİSYON)

- Baca gazı debisi: [m³ / h]
- Emisyon Değerleri
 - SO₂ [ppm]:
 - CO[ppm]:
 - CO₂[ppm]:
 - NO_x[ppm]:
 - PM (Particulate Matter, Katı Madde, Havada Asılı Partikül) [ppm]:
 - TRS (Total Reduced Sulfur, Toplam İndirgenmiş Kükürt) [ppm H₂S] :
 - Diğer bileşenler (Kloroform, uçucu organik bileşikler v.b.):
 - Sıcaklık [°C]:

C3. ATIK SU VE ATIK SU ARITMA TESİSİ

- Arıtma tesisi çalışmaya başlama tarihi:
- Arıtma tesisi tipi (Birden fazla seçenek işaretleyebilirsiniz.)
 - () Fiziksel () Kimyasal () Biyolojik
- Arıtma tesisi kapasitesi [m³ atık su / gün]:
- Arıtma tesisi giriş debisi [m³ / saat]:
- Arıtma tesisi çıkışından üretime dönen su debisi [m³ / saat]:
- Arıtma tesisi çıkışından doğaya deşarj olan su debisi [m³ / saat]:
- Deşarj olan suyun deşarj yeri:
 - () İrmak () Göl() Deniz () Yeraltı Suyu () Diğer:
- Arıtma tesisi giriş ve çıkış kirlilik değerleri ve fiziksel değerler:

	GİRİŞ	ÇIKIŞ
--	--------------	--------------

- | | | |
|---|-------|-------|
| • BOİ (Biyolojik Oksijen İhtiyacı) [mg/l] | ..... | ..... |
| • KOİ (Kimyasal Oksijen İhtiyacı) [mg/l] | ..... | ..... |
| • AKM (Askıda Katı Madde) [mg/l] | ..... | ..... |
| • pH | ..... | ..... |
| • Sıcaklık [°C] | ..... | ..... |
| • Birim su başına arıtma maliyeti (Ör: # TL / m ³ su) : | | |
| • Arıtma Tesisinde çıkan çamurun değerlendirilme veya bertaraf şekli: | | |
| | | |

D. ÇEVRE PERFORMANSINI ARTIRACAK TEKNOLOJİLERE BAKIŞ AÇISI

- Lütfen her ifadeye ilişkin katılma derecenizi aşağıdaki ölçeğe göre değerlendiriniz.

5. Kesinlikle Katılıyorum

4. Katılıyorum

3. Kararsızım

2. Katılmıyorum

1. Kesinlikle Katılmıyorum

Mevcut durum:

- D1. İşletmenin mevcut yasal çevre mevzuatına uyum düzeyi yüksektir. ()
- D2. Üretim hattında atıkların ve enerji kullanımının azaltılması konusunda iyileştirme çalışmaları yapılması gereken noktalar mevcuttur. ()
- D3. İşletme, atık ve kirlilik değerleri ile ilgili problemler yaşamaktadır. ()
- D4. İşletme, zaman zaman atık ve kirlilik değerleri ile ilgili cezai yaptırımlara maruz kalmaktadır. ()
- D5. İşletmede, kuruluştan bu yana çevre performansını arttıracak modernizasyonlar veya yatırımlar gerçekleştirilmiştir. ()

Yeniliklere açıklık:

- D6. İşletme yetkilileri ve çalışanları, çevre performansını artıracak yeni teknolojileri takip etmektedir. ()
- D7. İşletme, çevre performansını artıracak yeni teknolojiler için Ar-Ge ve yatırım bütçesi ayırmaktadır. ()
- D8. Çevre performansını artırıcı önlemler genellikle büyük yatırım gerektiren ve uygulaması zor tekniklerdir. ()
- D9. İşletme yetkililerinin çevre performansını artırmak için yapılacak yatırımların ulusal ve uluslararası kuruluşlar tarafından desteklendiği konusunda bilgisi vardır. ()
- D10. Çevre performansını artırıcı teknolojilerin uygulanması için Türkiye'deki üniversiteler ile işbirliği yapılması düşünülebilir. ()
- D11. Çevre performansını artırıcı teknolojilerin yurtdışındaki işletmelerden transfer edilmesi düşünülebilir. ()
- D12. Çevre performansını artırıcı teknolojilerin uygulanması için ulusal veya uluslararası sivil toplum kuruluşları ile işbirliği yapılması düşünülebilir. ()
- D13. İşletmede büyük yatırım gerektirmeden ve uygulaması basit tekniklerle çevre performansını artıracak çalışmalar yapılabilir. ()

Yenilikleri takip düzeyi ve şekli:

D14. İşletme yetkilileri ve çalışanları, çevre teknolojileri ile ilgili yurtiçi veya yurtdışı fuarları ziyaret etmektedir. ()

D15. İşletme yetkilileri ve çalışanları, çevre teknolojileri ile ilgili sektörel ve bilimsel yayınları takip etmektedir. ()

D16. İşletme yetkilileri ve çalışanları, çevre teknolojileri ile ilgili Internet sitelerini takip etmektedir. ()

D17. İşletme yetkilileri ve çalışanları, çevre teknolojileri ile ilgili yurtiçinde veya yurtdışında düzenlenen eğitim, konferans, sempozyum gibi etkinliklere katılım sağlamaktadır. ()

E. İŞLETMENİN ÇEVRE TEKNOLOJİLERİ ETKİNLİKLERİ

E1. İşletme yetkilileri ve çalışanlarının, çevre teknolojileri ile ilgili yurtiçi veya yurtdışında ziyaret ettikleri fuarlara ait ayrıntılı (Fuar adı, fuar yeri, fuar tarihi gibi) bilgi veriniz.

.....

.....

E2. İşletme yetkilileri ve çalışanlarının, çevre teknolojileri ile ilgili takip ettikleri sektörel ve bilimsel yayınlara ve Internet sitelerine ait ayrıntılı (Dergi, yayın veya Internet sitesi ismi, yayınlanan ülke gibi) bilgi veriniz.

.....

.....

E3. İşletme yetkilileri ve çalışanlarının son beş yıl içinde katıldıkları, çevre teknolojileri ile ilgili yurtiçinde veya yurtdışında düzenlenen eğitim, konferans ve sempozyum gibi etkinliklere ait ayrıntılı (Etkinlik ismi, tarihi, yeri, eğitimi veren kurum gibi) bilgi veriniz.

.....

.....

E4. Üretim ve çevre faaliyetleri ile ilgili yaşanan ve belirtilmek istenen sorunlar:

.....

.....

.....

.....

.....

.....

.....

APPENDIX – B

Table B1. Turkish pulp and paper producers

Company Name	City	Company Name	City
Viking Kağıt *	İzmir	Çopikas *	İstanbul
Levent Kağıt	İzmir	Dentaş *	Denizli
Tire Kutsan *	İzmir	Selkasan *	Manisa
Mopak	İzmir	Alkim *	İzmir
Türker Oluklu	İzmir	Akasan	Adana
İmsa	İzmir	Parteks *	Kayseri
Gökova Kağıt	Muğla	Harir Kağıt	İzmir
Sümer Holding	Mersin	Oyka Kağıt *	Zonguldak
Doğanpak	İzmir	Balıkesir Kağıt	Balıkesir
Ertaş Kağıtçılık	İzmir	Aykaç Aydın Kağıt	Aydın
Form Oluklu Mukavva	İzmir	Çumra Kağıt	Çumra
Özürün Kağıt	İzmir	Korsel	Eskişehir
Kalkan Ambalaj	İzmir	Toprak Kağıt *	Bilecik
Kutusan	İzmir	Meteksan	Ankara
Mersel Kağıt	İzmir	Marmara Kağıt *	Bilecik
Ekas Ege Kağıt	İzmir	K. Maraş Kağıt *	K. Maraş
Ve-Ge Hassas Kağıt	İzmir	Kombassan Kağıt	Konya
Kaplamın	İzmir	Kartonsan *	İstanbul
Hayat Kağıt *	Çorum	Modern Karton *	Tekirdağ
İpek Kağıt *	İzmit	Halkalı Kağıt *	İstanbul
Olmuksa *	Edirne		

* Members of SKSV (SKSV, 2005)

APPENDIX – C

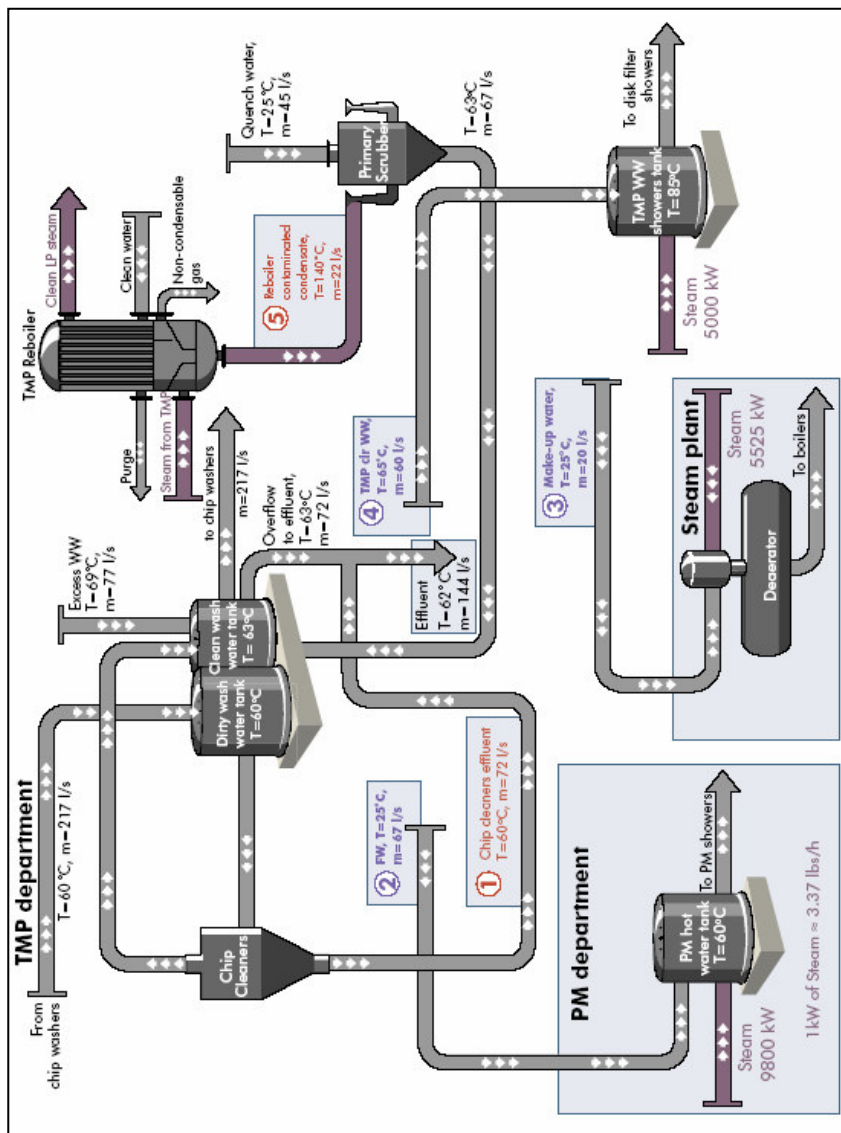


Figure C.1 Simplified flowchart of the system before retrofit

APPENDIX – C (Continued)

- Using the data given in Table 5.1, the hot and cold composite curves are drawn.

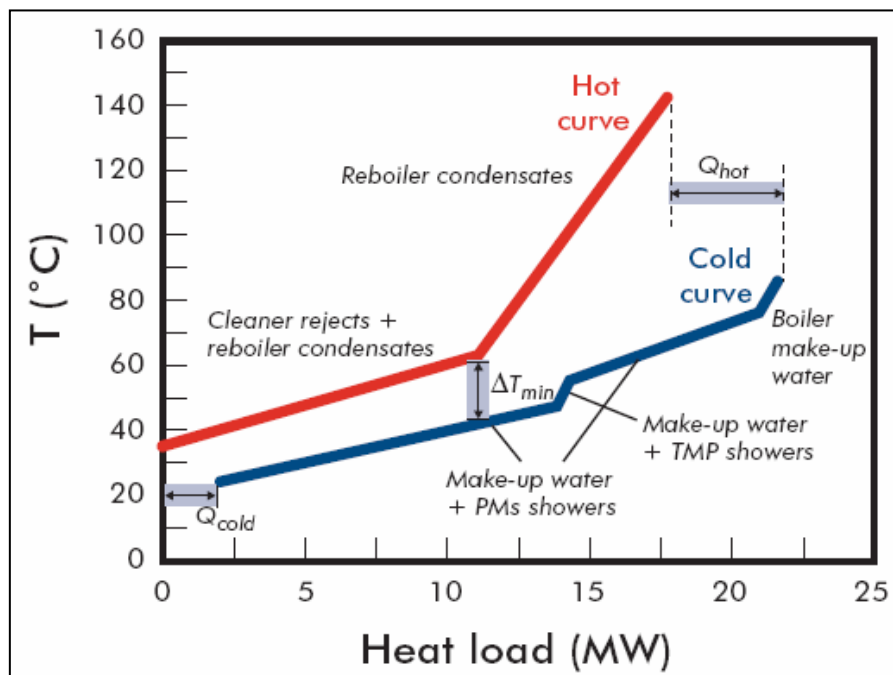


Figure C.2 Hot and cold composite curves

APPENDIX – C (Continued)

- Grid diagram of process streams and existing heat exchangers is drawn.

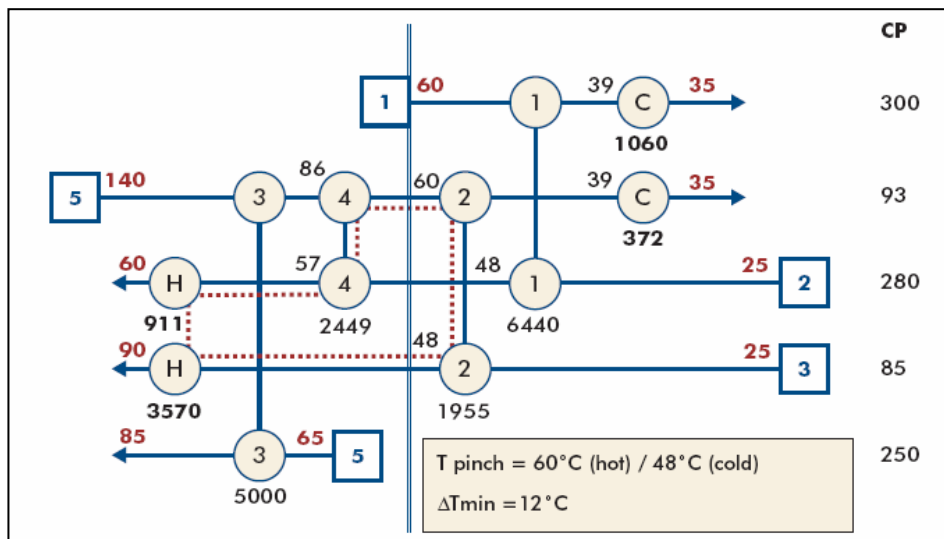


Figure C.3 Grid diagram before retrofit

APPENDIX – C (Continued)

- $Q_{\min \text{ cooling}}$, $Q_{\min \text{ heating}}$ and $\Delta T_{\min}$ values are calculated.

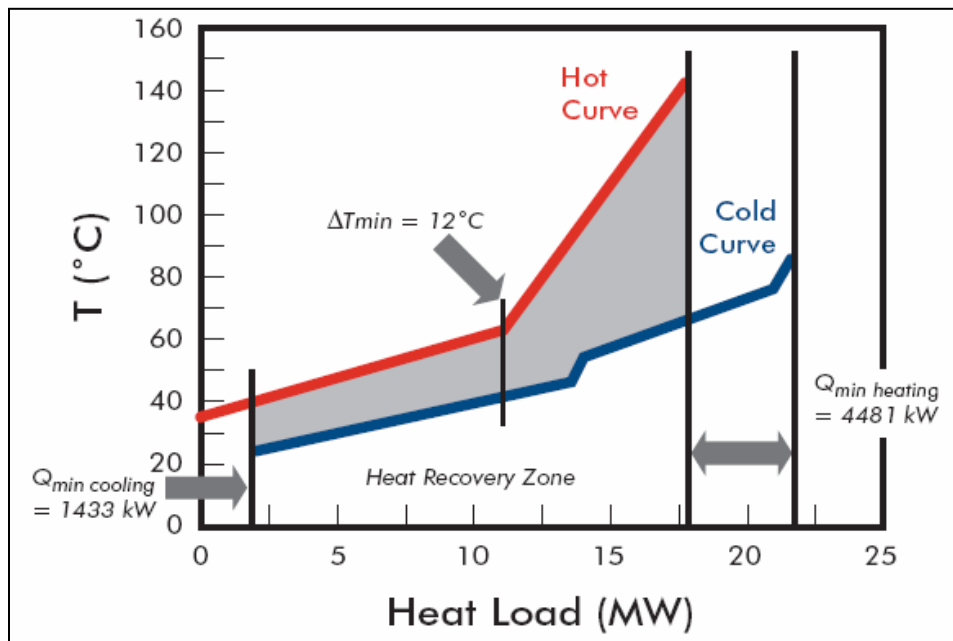


Figure C.4 Heat load versus temperature graph after calculations

Figure C.5 Grid diagram after retrofit



CURRICULUM VITAE

Levent ARSLAN is a Turkish citizen who was born in Samsun in 1980. After studying the first year of primary school in Karamürsel, he moved to Istanbul and completed his primary and secondary schools there and graduated from private Kalamış High School in 1998. The same year, he started his Chemical Engineering studies in Ege University in İzmir and gained his B. Sc. degree in 2002. During the last year of his undergraduate studies he attended formation classes and gained an English Teacher diploma from Ege University. In late 2002, he started an M. Sc. degree in Chemical Engineering Department of Ege University. In the beginning of 2003, he started working in KOSGEB Technology Development Center as a specialist. In 2004 he was awarded EU Jean Monnet Scholarship and was accepted to University of Amsterdam to study a 10 months post-graduate course in European Postgraduate Course In Environmental Management program in the Netherlands. After completing this course, he continued to his M. Sc. studies and wrote a thesis on “Environmental Impact Minimization in Pulp and Paper Industry”. Levent ARSLAN is still working for KOSGEB Technology Development Center and is also a part-time staff for EU IRC-EGE Innovation Relay Center.