Washington State Department of Ecology
Industrial Footprint Project

Resource Efficiency and Pollution Prevention and Control in the Pulp and Paper Industry

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1.0: Background

Paper is a global industry that includes fiber sourcing, pulping and paper production. These industrial processes, especially pulp and paper manufacture, are resource and chemical intensive at or near the top among manufacturing industries for water and energy consumption as well as releases to air and water (Environmental Paper Network 2007). A bleached kraft mill can use 14-20 million Btu of energy for every ton of pulp produced (EPA 2002). Recent advances in technological and non-technological pollution prevention and control measures have increased water and energy efficiencies and reduced pollution to air and water. For example, the sector achieved a 27% reduction of primary energy consumption between 1970 and 1994 (Worrell et al. 2001). Greater resource efficiencies and pollution prevention and control are being realized in two general areas: "in-plant processes" and "end-of-pipe processes." Options include: new processes, closed-systems, new bleaching technologies, and new recovery operations. For a complete review of best available technologies and a range of efficiencies in the European pulp and paper industry see Appendix 1.

2.0: Energy Efficiency

2.1: Energy Technologies

The U.S. paper industry required over 12 percent of total manufacturing energy use, in 1998, accounting for 2.7 quadrillion btus (Environmental Paper Network 2007). Paper making in the U.S. has been shown to be more energy intensive than in other countries (Worrell et al. 2001 and Appendix 1). Pulping and drying are the most energy intensive processes in paper making. Much of its own energy is produced by the industry on its own from on-site biomass, but the remainder is purchased or generated from fossil fuels burned on site. Many energy efficiencies have been achieved with the advent of modern technologies, resulting in a 27% reduction of primary energy consumption between 1970 and 1994 (Worrell et al. 2001). This reduction has mainly been realized in process efficiency improvements and increased combined heat and power capacity.

Pinch analysis, which is derived from process integration or a holistic approach top process design, retrofitting, and operation, is an effective and practical tool for energy and water management in the pulp and paper industry (Koufos and Retina 2001). Pinch analysis is the basis of process integration which emphasizes the unity of process in a manufacturing system. Pinch analysis starts by identifying and defining energy load and temperatures of each individual process in a facility. Composite curves are drawn representing process heating and cooling as heat flow versus temperature. Where these curves come closest together is the "pinch." Where heat is higher than the temperature at which it is required is where energy is available for recovery. This way the minimum thermal energy required to operate the facility is identified and energy savings can be realized.

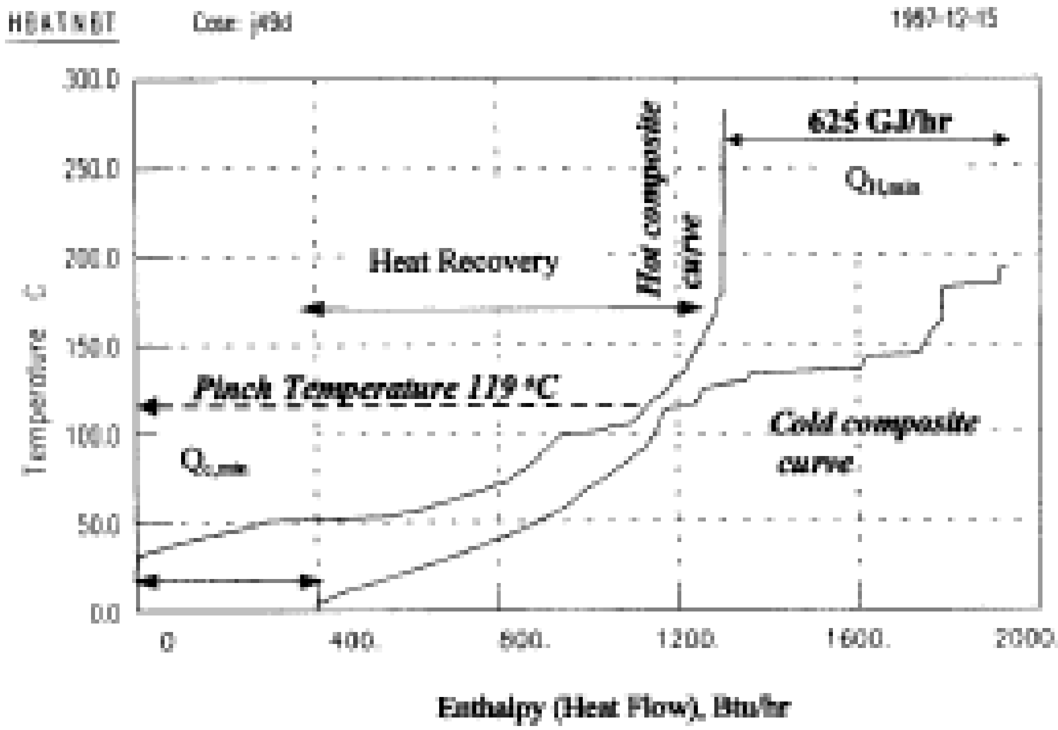

Figure 1. Energy Pinch Analysis (Koufos and Retsina 2001).

Existing technologies as well as emerging technologies can reduce overall energy use in the industry and an exhaustive list is found below in Table 1. For example, due to the high energy demand of pulping and drying, simply increasing the mix of recycled or recovered paper pulp with virgin pulp can result in significant energy efficiencies. In 1994, wastepaper rather than virgin wood pulp accounted for 32% of all pulp in U.S. manufacturing and an additional increase of 15% could result in energy savings of 13.4 Gigajoules per ton of pulp produced (GJ/t) of steam and 2.06 GJ/t of electricity (Worrell et al. 2001).

Table 1: Energy Savings, Costs, and Carbon Dioxide Emissions Reductions for Energy-Efficient Technologies and Measures Applied to the U.S. Pulp and Paper Industry in 1994 (From Worrell et al. 2001).

	Production	Fuel Savings	Electricity Savings	Primary Energy Savings	Carbon Savings	Retrofit Cost of Measure	Annual Operating Cost Change	Applicable Share of Production
Measure	(Mt)	(GJ/t)	(GJ/t)	(GJ/t)	(kg/t)	(US$/t)	(US$/t)	%
Raw Materials Preparation								
Ring style debarked	241.5	0.00	0.02	0.03	0.5	1.3	-0.01	15%
Cradle debarked	241.5	0.00	0.03	0.05	0.8	25.8	0.0	15%
Enzyme-assisted debarked	241.5	0.00	0.02	0.04	0.7	3.9	0.0	15%
Bar-type chip screens	49.5	0.35	0.00	0.50	3.1	1.5	-0.7	20%
Chip conditioners	49.5	0.21	0.00	0.30	1.9	N/A	-0.4	30%
Improved screening processes	49.5	0.35	0.00	0.50	3.1	1.5	-0.7	20%
Belt conveyors	239.4	0.00	0.02	0.04	0.7	N/A	-0.5	20%
Fine-slotted wedge wire baskets	5.3	0.00	0.61	1.24	19.4	N/A	N/A	10%
Pulping: Mechanical								
Refiner Improvements	3.2	0.00	0.81	1.63	25.6	7.7	2.6	20%
Befouling	5.3	-0.50	2.04	3.41	60.1	27.0	9.4	20%
Pulping: Thermo mechanical (TMP)								
RTS	3.0	0.00	1.10	2.23	35.0	50.0	0.0	30%
LCR	3.0	0.00	0.51	1.04	16.3	N/A	0.0	5%
Thermo pulping	3.0	0.00	1.10	2.20	35.0	226.7	N/A	15%
Super Pressurized ground wood	3.0	0.00	2.67	5.40	84.7	220.0	-2.6	10%
Heat recovery in TMP	3.0	6.05	-0.54	7.52	37.4	21.0	18.0	20%
Improvements in Chemi-TMP	3.0	0.00	1.10	2.23	35.0	300.0	N/A	20%
Pulping: Chemical								
Continuous digesters	49.5	6.30	-0.27	8.40	48.1	196.0	0.0	25%
Continuous digester modifications	49.5	0.97	0.00	1.39	8.8	1.3	0.2	50%
Batch digester modifications	49.5	3.20	0.00	4.55	28.8	6.6	0.5	15%
Chemical Recovery								
Falling film black liquor evap.	53.2	0.80	0.001	1.14	10.1	90.00	0.00	30%
Tamp Ella recovery system	53.2	2.90	0.0	4.13	23.9	N/A	N/A	1%
Lime kiln modifications	53.2	0.46	0.0	0.46	7.82	2.50	N/A	20%

Extended Delignification and Bleaching								
Ozone bleaching	29.6	0.00	0.01	0.02	0.3	149.5	-2.0	25%
Brown stock washing	29.6	0.01	0.05	0.11	1.5	50.0	-2.3	15%
Washing presses (post-delignification)	29.6	0.39	0.00	0.55	3.5	17.0	-0.5	15%
Papermaking								
Gap forming	82.5	0.00	0.15	0.30	4.7	70.0	0.7	35%
High consistency forming	70.6	1.50	0.15	2.43	18.2	70.0	0.7	20%
Extended nip press (shoe press)	82.5	1.60	0.00	2.28	14.4	37.6	2.2	40%
Hot pressing	82.5	0.61	0.00	0.87	5.5	25.7	0.0	10%
Direct drying cylinder firing	82.5	1.05	0.00	1.50	9.5	111.2	1.4	5%
Reduced air requirements	82.5	0.76	0.02	1.12	7.5	9.5	0.1	40%
Waste heat recovery	82.5	0.50	0.00	0.71	4.5	17.6	1.6	30%
Condebelt drying	82.5	1.60	0.07	2.43	16.7	28.2	0.0	50%
Infrared profiling	82.5	0.70	-0.08	0.84	3.8	1.2	0.0	15%
Dry sheet forming	82.5	5.00	-0.75	5.59	21.2	1504.0	0.0	15%
General Measures								
Optimization of regular equipment	82.5	0.00	0.10	0.20	3.4	N/A	1.0	30%
Energy-efficient lighting	82.5	0.00	0.05	0.10	1.6	1.20	-0.01	20%
Efficient motor systems	82.5	0.00	0.62	1.25	19.6	6.00	0.0	100%
Pinch analysis	82.5	1.79	0.00	2.54	16.1	8.00	0.0	20%
Efficient Steam Production and Distribution								
Boiler maintenance	82.5	1.26	0.00	1.79	11.3	0.0	0.06	20%
Improved process control	82.5	0.54	0.00	0.76	4.8	0.4	0.08	50%
Flue has heat recovery	82.5	0.25	0.00	0.36	2.3	0.7	0.09	50%
Lowdown steam recovery	82.5	0.23	0.00	0.33	2.1	0.8	0.11	41%
Steam trap maintenance	82.5	1.79	0.00	2.54	16.1	1.2	0.09	50%
Automatic steam trap monitoring	82.5	0.89	0.00	1.27	8.0	1.2	0.16	50%
Leak repair	82.5	0.54	0.00	0.76	4.8	0.3	0.03	12%
Condensate return	82.5	2.68	0.00	3.81	24.1	3.8	0.54	2%
Fiber Substitution								
Increase use of recycled paper	60	13.4	2.1	22.4	186	485	-73.9	15%

Worrell et al. (2001) list nine promising technologies for reducing energy consumption in the pulp and paper industry: (1) black liquor gasification; (2) new drying technologies such as Impulse and Condebelt drying; (3) dry sheet forming; (4) high consistency forming; (5) electrolytic causticising; (6) advance adjustable speed drives; (7) advanced gas turbines; (8) low-NOx high efficiency boiler designs; and, (9) membrane technology for wastewater treatment.

2.2: Range of Energy Use Efficiencies

The range of efficiencies for energy use reported in annual corporate sustainability reports are noted below. The figures have not yet been converted to an equivalent basis since they vary in terms of what is being measured – i.e. total energy, fossil energy, electricity. See also Appendix 1 for a range of European efficiencies.

- Catalyst (electricity intensity): 1.47 to 3.01 megawatt hours per air dried ton of product.
- International Paper (energy intensity): 32 gigajoules per metric ton of product.
- Nippon (Japan-wide): 14.5 gigajoules per metric ton of product.
- Norske (energy intensity): 12.6 gigajoules per metric ton of product.
- Oji (fossil energy, Tomakomai mill): 347 liters oil equivalent per metric ton of product.
- Stora Enso (electricity consumption): 1.31 – 1.38 megawatt hours per metric ton of product.
- Votorantim (energy consumption): 617 – 1,274 kilowatt hours per air dried ton of product.
- Weyerhaeuser (energy intensity): 23.9 to 24.8 million BTUs per ton of production.

3.0: Water Efficiency

3.1: Water Technologies

The paper industry is the largest user (per unit of product) of industrial process water in the United States (EPA 2002). In the U.S., a typical mill manufacturing virgin, bleached chemical pulp can use between 4,000 and 12,000 gallons/ton produced (EPA 2002). Pulp and paper facilities have employed pinch analysis to improve water efficiency. Pinch analysis specific to water use in the pulp and paper industry has been trademarked as Successive Design Methodology (SDM™) and Operational Pinch, (O-Pinch™) (American Process Inc.), "Water Close"™ and has resulted in fresh water savings of 15-40% and wastewater savings of 20-50% (Koufos and Retsina 2001). Water pinch analysis requires identifying the water sources and sinks in a process and where the resulting graphical curves are closest is called the pinch. The overlap between the curves indicates the potential scope for water re-use.

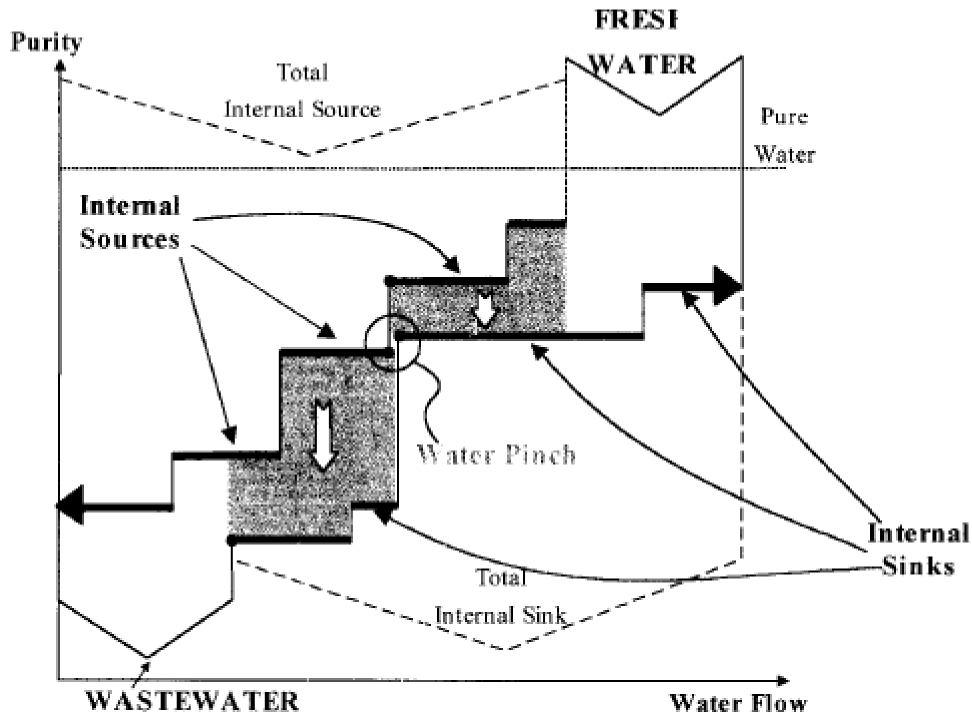

Figure 2. Composite curves for water pinch analysis (Koufos and Retsina 2001).

Successive Design Methodology (SDM™) uses an integrated approach to examine site operation and utilities to identify synergies between water, electricity, and steam conservation efforts. Weyerhaeuser Company in its Longview Mill plant-wide energy assessment used SDM™ to identify measures that would reduce site water consumption by 3,600 gallons per minute (gpm) for a savings of $3.1 million annually (DOE 2004). Table 2 below identifies the measures and their water and energy savings as well as financial savings.

Table 2: Weyerhaeuser Company Longview Mill Assessment Recommendations and Estimated Savings (DOE 2004).

Process Description	Water Savings (gallons per minute)	Natural gas Savings (MMBtu/yr)	Estimated Annual Savings
Improve digester washing and reduce dilution factor	200	310,000	$580,000
Change evaporator area configuration	1,750	570,000	$650,000
Add digester heat recovery	0	130,000	$280,000
Modify heated water system	0	80,000	$150,000
Re-use white water & modify water system	1,250	100,000	$220,000
Upgrade condensate polisher and increase condensate return	200	190,000	$390,000
Add waste heat boiler on incinerator exhaust	0	110,000	$180,000

Process Description	Water Savings (gallons per minute)	Natural gas Savings (MMBtu/yr)	Estimated Annual Savings
Implement recaust dissolving tank temperature control	200	0	$0
Add water/glycol system for heating building and process ventilation air	0	310,000	$650,000

Visy, an Australian-owned, integrated packaging and recycling company has used water recycling systems to reduce its fresh water use by 11% since 2004 while increasing its production output (Visy 2007).

An additional technology to reduce water use in the pulp and paper industry is to recycle effluent in a "closed-cycle concept." (Oliveira et al. 2007). In this process, whitewater - the excess water originating from pulp stock dewatering and other fibre-contaminated water - is subject to membrane ultrafiltration (UF) in the paper machine and in the pulp bleach plant. In order for the wastewater to be re-used in the pulp bleach plant, it must be subject to a combined treatment of UF and precipitation to remove hardness.

Rangan (Undated) identifies sixteen methods for the reduction in water consumption in the paper industry:

1. Maximum recycling of back water at various stages;
2. Improvement in washing and screening;
3. Maximum recycling of condensate;
4. Prevention of accidental losses, leakages from pump glands, valves, pipe line and other sources to be attended immediately;
5. Collection of spillage and recycling of concentrated spill to the system and weak spill to spill lagoon to avoid contamination of whole effluent steam. Collection and recycling from black liquor, fresh liquor and chemic al dosing pump to the system and immediate repair of units, have been found to be very effective in reducing color and toxicity and improving recovery of chemicals;
6. Maintaining the steam pressure above digester cooking pressure and routing check-up of non-return valves and timely replacement to avoid return of cooking liquor to condensate line;
7. Metering and monitoring of water consumption of every unit;
8. Washing of wood and bamboo to avoid carryover of dust and other foreign materials to subsequent stages;
9. Separation of centricleaner rejects from main drain and collection of fiber to avoid contamination of whole system;
10. Recovery of all alkali from dregs of green liquor by centrifuge;
11. Use of back water strictly in hose pipe for floor washing and other uses;
12. Use of clarified and treated back water for causticising at various stages in pulp mill and paper machines, especially for kraft paper;
13. Use of back water in waster paper pulping plant;

14. Use of evaporator condensate in causticising section, pulp washing, dreg washing, dilution in screening and centricleaning;
15. Use of contaminated back water from pulp mill and recovery section drain in coal moistening, ash quenching surface condenser and bamboo washing; and,
16. Good house keeping, general consciousness regarding water conservation and monitoring by a separate cell.

3.2: Range of Water Use Efficiencies

The range of efficiencies for water use reported in annual corporate sustainability reports are noted below. However, these figures are not always directly comparable in that facilities vary widely in the product produced. See also Appendix 1 for a range of European efficiencies.

Of those companies that reported by unit produced, the efficiencies listed were International Paper: 62 cubic meters/ton (2004 ave.), Boise: 14,400 gallons/ton (2005), Visy: 4 kilolitre/ton (2006), Votorantim: 23 – 49.6 m3/t (2006).

4.0: Pollution Prevention and Control

4.1: Water Pollution

The chief water pollution categories for pulp and paper mills are: effluent solids (TSS), chlorinated compounds, such asfurans, dioxins, and absorbable organic halides [AOX], chemical oxygen demand (COD), biochemical oxygen demand (BOD) and color. The U.S. pulp and paper industry ranks fourth among manufacturing industries in releases of dioxin and dioxin-like compounds to the air and third in releases to surface water (Environmental Paper Network 2007).

Pulping is accomplished in three general processes: chemical, mechanical, and chemi-mechanical (a combination of both). The largest portion of water pollution comes from the bleaching process. The industry trend is to avoid the use of any kind of chlorine chemicals and instead use total chorine-free bleaching, but some grades of pulp still require elemental chlorine-free processes which use chlorine dioxide. Several manufacturing practice categories have been suggested for pollution prevention and control: input substitution, product reformulation (eliminate chemical usage), process modification (change pulping and bleaching methods), improved housekeeping, and closed-loop recycling. (Chritchfield Undated). Advances in elemental chlorine-free bleaching processes have drastically reduced the chlorinated compound effluents.

4.2: Water Pollution Technologies

Pollution abatement in the pulp and paper industry largely focuses on two strategies: 1) new in-plant processes (e.g. pulping) focusing on better delignification such as extended, oxygen, or ozone delignification and the replacement of chlorine for bleaching and 2) “end-of-pipe” biological treatment processes that include hybrid anaerobic and aerobic digestion (Murray 1992). Biological treatment systems, such as activated sludge, aerated lagoons, and anaerobic fermentation, can reduce BOD by over 99% and achieve a COD reduction of 50% to 90%

(World Bank Group 2007). Tertiary treatment may be performed to reduce toxicity, suspended solids, and color. Solid waste treatment steps include dewatering of sludge and combustion in an incinerator, bark boiler, or fossil-fuel-fired boiler. Sludges from a clarifier are dewatered and may be incinerated; otherwise, they are landfilled.

The World Bank Group (2007) list several process recommendations for reducing wastewater discharges:

- Minimize the generation of effluents through process modifications and recycle wastewaters, aiming for total recycling.
- Reduce effluent volume and treatment requirements by using dry instead of wet debarking; recovering pulping chemicals by concentrating black liquor and burning the concentrate in a recovery furnace; recovering cooking chemicals by recausticizing the smelt from the recovery furnace; and using high-efficiency washing and bleaching equipment.
- Minimize unplanned or non-routine discharges of wastewater and black liquor, caused by equipment failures, human error, and faulty maintenance procedures, by training operators, establishing good operating practices, and providing sumps and other facilities to recover liquor losses from the process.
- Reduce bleaching requirements by process design and operation. Use the following measures to reduce emissions of chlorinated compounds to the environment: before bleaching, reduce the lignin content in the pulp (Kappa number of 10) for hardwood by extended cooking and by oxygen delignification under elevated pressure; optimize pulp washing prior to bleaching; use TCF or at a minimum, ECF bleaching systems; use oxygen, ozone, peroxides (hydrogen peroxide), per acetic acid, or enzymes (cellulose-free xylonite) as substitutes for chlorine-based bleaching chemicals; recover and incinerate maximum material removed from pulp bleaching; where chlorine bleaching is used, reduce the chlorine charge on the lignin by controlling pH and by splitting the addition of chlorine.

The Indiana Department of Environmental Management (2007) recommends the following measures:

- Implement a delignification process. Delignification processes include: extended delignification, oxygen delignification, ozone delignification, enzyme treatment of pulp, or using an anthraquinone catalyst.
- Improved brownstock and bleaching stage washing to reduce the amount of bleaching chemicals required. Modern washing methods include (1) atmospheric or pressure diffusion washers; (2) belt washers; (3) pulp presses; (4) using acid filtrates from hypochlorite or chlorine dioxide stages can be used as dilution and wash water for the first bleaching stage (counter-current washing); (5) using second extraction stage filtrates can be used as dilution and wash water in the first extraction stage (counter-current washing).
- A spill control system for black liquor including the following: (1) physical isolation of equipment containing black liquor; (2) floor drainage systems that allow black liquor

spills to be collected and controlled; (3) back up black liquor storage capacity; (4) spill sensors, and (5) enclosing washing and screening equipment.

- Improved chipping and screening to attain the appropriate chip thickness.
- Utilize oxygen-reinforced and peroxide-reinforced extraction processes to reduce the amount of chlorine and / or chlorine dioxide needed while increasing the pulp brightness.
- Using chemical application control and monitoring systems to avoid excess concentrations of chlorine based chemicals within reactor vessels.
- Investigate reuse and recycling options for the paper sludge waste.
- Seek beneficial disposal methods for secondary treatment biosolids removed during the wastewater treatment process.
- Use process chemicals that do **not** contain Nonylphenol / Nonylphenol ethoxylates (NP/NPE).
- Switch to a total chlorine free bleaching process.
- When possible cover tanks and keep all lids closed to prevent air releases
- Perform an energy use audit to identify ways to reduce energy consumption.

4.3: Range of Water Pollution Loads

The following pollution load levels can be achieved by adopting good industrial practices: COD, 35 kilograms per ton (kg/t) (aim for 15 kg/t); AOX, 2 kg/t of Air Dried Pulp (ADP) (aim for 0.2 kg/t); total phosphorus, 0.02 kg/t; total nitrogen, 0.15 kg/t; and solid waste generation, 150 kg/t of ADP (World Bank Group 2007).

The range of intensities for water pollution reported in annual corporate sustainability reports are noted below. However, these figures are not always directly comparable in that the figures are sometimes reported by unit of production but more often are reported as overall annual consumption. In addition, the facilities vary widely in the product produced annually. See also Appendix 1 for a range of European efficiencies.

Of those companies that reported by unit produced, minimum intensities listed were:

Company	BOD	TSS	AOX	COD
Aracruz (2006)	.23 kg/adt	.56 kg/adt	.10 kg/adt	3.52 kg/adt
Boise (2005)	3.2 lbs/ton	-	.34 kg/t	-
International Paper (2004)	1.5 kg/adt	2.1 kg/adt	-	-
Mondi (2004)	-	-	-	5.6 kg/adt
Votorantim (2006)	.4 kg/adt	-	.05 kg/adt	-

4.4: Air Pollution

The pulp and paper industry use over 12 percent of all manufacturing energy consumed in the United States (Environmental Paper Network 2007). The majority of total toxic release inventory attributable to the industry is into the air (66%) (EPA 2002). The significant increase in the use of recycled fiber as well as self-generated power (biomass) has contributed to better energy efficiency in the industry and carbon intensity (emissions per unit of product) has rapidly declined. (Worrell et al. 2001). Existing and emerging technologies represent promising additional reductions in consumption and even better efficiencies. For example, Worrell et. al. (2001) demonstrates potential cost-effective savings of 16% of 1994 primary energy use and up to 24% when recycling is included. See Table 1 above.

Air pollution from the pulp and paper industry includes greenhouse gas emissions, sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter (PM), hazardous air pollutants (Haps), volatile organic compounds (Voss), total reduced Sulphur (odor), and mercury (Hg).

4.5: Air Pollution Technologies

According to the World Bank Group, the following process recommendations can help to achieve target air pollution levels:

- Use energy-efficient pulping processes wherever feasible. Acceptability of less bright products should be promoted. For less bright products such as newsprint, thermo-mechanical processes and recycled fiber may be considered.
- Minimize sulfur emissions to the atmosphere by using a low-odor design black liquor recovery furnace.
- Use energy-efficient processes for black liquor chemical recovery, preferably aiming for a high solid content (70%) (World Bank Group 2007).

4.6: Range of Air Pollution Levels

The range of efficiencies for air pollution reported in annual corporate sustainability reports are noted below. However, these figures are not always directly comparable in that the figures are sometimes reported by unit of production but more often are reported as overall annual consumption. In addition, the facilities vary widely in the product produced annually. See also Appendix 1 for a range of European efficiencies.

Of those companies that reported by unit produced, the intensities listed were:

Company	SO2	NOX	PM	TRS
Aracruz (2006)	.20 kg/adt	.25 kg/adt	-	-
Boise (2005)	2.6 lbs/ton	3.8 lbs/ton	-	-
International Paper (2004)	3.8 kg/adt	2.5 kg/adt	0.8 kg/adt	-
Votorantim (2006)	.04 kg/adt	.97 kg/adt	-	.01 kg/adt

5.0: Certification System Evaluations

Forest and pulp and paper certification is a system in which forestry operations or pulp and paper products can receive a stamp of approval ensuring that they are environmentally and socially responsible, giving consumers the confidence and power to “vote” with their dollars.

Metafore, a non-profit organization for businesspeople focused on evaluating, selecting and manufacturing environmentally preferable wood and paper products, developed profiles describing different certification systems as well as a Forest Certification Comparison Matrix which provides information on the key aspects of certification systems with a presence in the

North American market (Metafore 2007). The relative attributes and characteristics of some of the world's largest forest certification systems are compared within an objective framework in the matrix (See Table 3). The International Organization for Standardization (ISO) offers internationally accepted guidance for establishing and maintaining a credible certification system. There are several certification systems relevant to the North American marketplace:

- The Forest Stewardship Council (FSC) is an international system covering forest management practices and the tracking and labeling of certified forest and paper products.
- The Sustainable Forestry Initiative® (SFI) is a sustainable forest management standard targeting large industrial operations in Canada and the United States.
- The American Tree Farm System (ATFS) is a program for certifying the practices of non-industrial forestland owners, which is defined as owning less than 10,000 contiguous acres and not being affiliated with a forest products processing facility.
- The Canadian Standards Association (CSA) applies to Canadian operations and is a national standard for sustainable forest management and tracking and labeling certified material.
- The Programme for the Endorsement of Forest Certification Schemes (PEFC) is a mutual recognition framework for national forest certification standards.
- Additionally, there is the American the Forest Stewardship Program (USFS) and Green Tag (Nat. Forestry Association) as well as several emerging forest certification systems in Asia, Australia and South America.

Two certification programs are popular in the U.S., the non-profit FSC founded in 1993 and the industry-standard SFI founded in 1995.

The systems vary largely in their scope of criteria, plan - rigor or detail, type of professional reviewer, rigor of review/assessment, and costs and benefits and have received variable reception from environmental organizations. According the Natural Resources Defense Council, SFI lacks certain protections of the FSC such as: preventing natural forests from conversion to plantations, protection of old growth in the U.S., protection of sensitive, rare, and state-listed threatened and endangered species, and control of clear cutting (NRDC 2002).

There have been numerous reviews of the two certification systems, including two that were "independent." One measure of the difference in the systems is that in the time that FSC had certified 70 million acres in 54 countries in 9 years, SFI had nearly certified the entire U.S. industrial timber base in two years. Despite serious differences identified in the numerous comparisons, the most "independent" study, sponsored by both SFI and the AF&PA, found differences in 24 areas and 7 similarities. According to NRDC (2002), the overall difference is captured best in the program's objectives: SFI establishes a baseline of performance to encourage improvement while FSC establishes a high standard for exemplary management.

Table 3. Metafore 2007 Forest Certification Comparison Matrix. ©

Criteria	American Tree Farm Systems	Canadian Standards Association	Forest Stewardship Council	Programme for Endorsement of Forest Certification Schemes	Sustainable Forestry Initiative
THE BASICS					
Basis for Company Participation	Voluntary	Voluntary	Voluntary	Voluntary	Voluntary
Scope	Private, non-industrial forests in the United States.	Focus on all forest types in Canada.	Focus on all forest types throughout the world.	PEFC is a mutual recognition body that endorses national systems throughout the world.	Primarily focused on large-scale forests in the United States and Canada.
Number of participants	88,000 Certified Tree Farmers in 46 states.	There are 28 companies in Canada with 89 forest management certificates. There are 31 companies with 61 Chain of Custody certificates.	There are 877 Forest Management certificates and 6887 Chain of Custody certificates in 89 countries.	PEFC Council has formally endorsed 22 national systems. These cover 1121 forest management certificates and 3123 chain of custody certificates.	In the United States and Canada, there are 219 program participants.
Total land area	9.7 million hectares in the U.S. (24 million acres)	84,776,173 hectares (209,486,487 acres) in Canada.	96,044,454 hectares (237,331,014 acres) globally, 33,619,595 hectares (83,075,828 acres) in North America.	200 million hectares (494 million acres) globally.	55,708,517 third-party certified hectares (137,658,743 acres) in Canada and the U.S.
GOVERNANCE: MANAGING THE SYSTEM					
Oversight	National operating committee and individual state committees.	A 27 member Board of Directors.	The General Assembly consists of all FSC members who fall into three chambers-economic, social and environmental. The Board of Directors consists of nine individuals with three representing each chamber.	A General Assembly and a Board of Directors consisting of a chairman two vice chairman and between 2 and 10 members.	The 15 member Board of Directors manages the standard setting, fiber tracking, labeling and certification process.

Representation	Tree farmers and forestry professionals.	Academic, government, industry and consulting sectors.	Academic, government, industry and consulting sectors.	The General Assembly consists of representatives from the 33 member countries reflecting major interest parties supporting PEFC, geographical distribution of members and a gender balance.	Evenly split among SFI program participants, the conservation & environmental community and the broader forestry community.
STANDARDIZATION: DEVELOPING THE STANDARD					
Development	Set by independent standards review panel consisting of academia, environmental organizations, forest industry, forest owners, professional logging community, and government.	Set by a technical committee with representatives from academia, government, industry and general interest groups.	Set by national and regional standards working groups with representation open to businesses, environmental groups, auditors, individuals and government.	PEFC national governing bodies coordinate the setting process, which is set by invited parties including forest owners, industry, nongovernmental groups, unions and retailers.	Set by the Board of Directors and implemented by the Resources Committee with two thirds of representation from academic, government and conservation organizations and the rest from the forest products industry.
Scope	Environmental and silvicultural issues.	Environmental, silvicultural, social and economic issues.	Environmental, silvicultural, social and economic issues.	Environmental, silvicultural, social and economic issues.	Environmental, silvicultural, social and economic issues.
Public Input	Subject to 60 day public review.	Subject to public review.	Subject to public review.	The final draft of a system is subject to 60 days public consultation as minimum.	Subject to public review.
Approval	American Forest Foundation Board of Trustees	Standards Council of Canada.	National Board and FSC International Secretariat	PEFC Council assesses for purpose of endorsement.	Board of Directors
Updating	Every 5 years.	Every 5 years.	Every 5 years.	Every 5 years.	Every 5 years.
ACCREDITATION: AUDITOR QUALIFICATIONS					

Reviewer	ATFS	Standards Council of Canada.	FSC Accreditation Unit	The relevant national accreditation body which is a member of International Accreditation Forum.	ANSI-ASQ National Accreditation Board (ANAB) or In Canada, the Standards Council of Canada (SCC)
Evaluation Process	Voluntary inspectors subject to education and experience requirements and completion of a national training curriculum.	Task group reviews application and forest management audit.	Task group audits the applicant's office and audits organizations that have been already evaluated by the applicant.	A task group examines documentation, qualifications of reviewers and dispute resolution procedures.	Auditors application process which includes an on-site and witness assessment process.
Approval	ATFS	An executive committee makes a decision based on task group findings.	An executive committee makes a decision based on task group findings.	A separate group decides based on task group findings.	The ANAB's independent Accreditation Council.
Monitoring	None	Annually assessed.	Regularly assessed.	Annually assessed.	Annually assessed.
Renewal	Every 5 years.	Every 5 years.	Every 5 years.	Every 5 years.	Every 5 years.
VERIFICATION: JUDGING CONFORMANCE TO THE STANDARD					
Reviewer	Voluntary third-party Inspector	Accredited third party auditor.	Accredited third party auditor.	Accredited third party auditor.	Accredited third party auditor.
Evaluation Process	Inspectors review forest management plan and operations.	Audit team discusses scope of assessment with applicant and conducts in field review.	Audit team reviews documentation, conducts a field assessment and interviews relevant parties.	Endorsed systems require audits that consist of a documentation review and an on-site assessment.	Audit team reviews documentation, conducts a field assessment and interviews relevant parties.
Approval	Approved by Voluntary Inspector.	An executive committee decides based on audit findings and assessment team's activities.	An executive committee decides based on profile and feedback from applicant and two impartial peer reviews.	An executive committee makes a decision based on task group findings.	Audit team grants approval based on resolution of non-compliance issues.
Public Input	No direct public input.	Any member of the public can file a dispute if there is a disagreement with the decision or ongoing	Any member of the public can file a dispute if there is a disagreement with the decision or ongoing	External parties are allowed to provide submissions to inform the audit.	Any member of the public can file a dispute if there is a disagreement with the decision or ongoing

		compliance to the standard.	compliance to the standard.		compliance to the standard.
Monitoring	No requirements.	Annual field review.	Annual field review.	Certificate holders are assessed annually.	Option to have a full audit every 5 years or regular assessments over a 5-year period. Annual reviews required for product label users.
Renewal	Every 5 years.	Every 3 years.	Every 5 years.	Every 5 years.	Every 5 years.
PRODUCT TRACKING AND CLAIMS					
Material Tracking	None	Chain of Custody tracks products from forest through each stage of manufacturing and distribution.	Chain of Custody tracks products from forest through each stage of manufacturing and distribution.	Chain of Custody tracks products from forest through each stage of manufacturing and distribution.	Participants required to have auditable monitoring system to account for all wood flows. Participants can also have Chain of Custody certification to track products from forest through each stage of manufacturing and distribution.
On-Product label	None	Yes, three product labels: 1) 100% from a certified forest; 2) product line from a certified forest with a minimum of 70% certified; and 3) a product with a minimum 70% certified forest content.	Yes, 3 product labels: 1) FSC pure label for 100% certified product group; 2) FSC mixed label with a minimum threshold of 10% certified and 60% post consumer content; and 3) FSC recycled label for product groups with 100% post consumer content.	Yes, but a minimum 70% certified content threshold is required for a product to qualify to use the label.	Yes, seven product labels are available. 1) a label for primary producers 2) four labels for secondary producers. 3) 100% from a SFI certified forest, and 4) SFI mixed label with xx% content from a SFI certified forest.
Use of non-certified sources in labeled products	Not applicable	Yes, prohibits use of sources that are illegally harvested.	Yes, prohibits use of sources that are illegally harvested and derived from a high conservation value forest.	Yes, but "non-certified" raw material shall not originate from illegally harvested sources.	Yes, prohibits use of illegally harvested sources.

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Appendix 1.
Best Available Techniques and Range of Emissions in the European Pulp and Paper Industry.

Presented in this appendix are the summary findings of a Best Available Techniques Reference Document published in 2001 by the European Commission. The best available techniques (BAT) and emissions to air and water figures represent a range at the sector level in terms of techniques, raw materials, energy sources, products and processes in the European paper industry. The figures are reported in yearly averages and under standard conditions. The processes that are considered include: Kraft pulp production, sulfite pulp production, mechanical and chemi-thermo-mechanical pulp production, recovered paper processing, paper-making, and the production of power and steam from auxiliary boilers. First presented is European BAT for each process and in the tables are presented the European range of emissions to air and water from the processes considered.

Best available techniques for kraft pulp mills are considered to be:

- Dry debarking of wood.
- Increased delignification before the bleach plant by extended or modified cooking and additional oxygen stages.
- Highly efficient brown stock washing and closed cycle brown stock screening.
- Elemental chlorine free (ECF) bleaching with low AOX or Totally chlorine free (TCF) bleaching.
- Recycling of some, mainly alkaline process water from the bleach plant.
- Effective spill monitoring, containment and recovery system.
- Stripping and reuse of the condensates from the evaporation plant.
- Sufficient capacity of the black liquor evaporation plant and the recovery boiler to cope with the additional liquor and dry solids load.
- Collection and reuse of clean cooling waters.
- Provision of sufficiently large buffer tanks for storage of spilled cooking and recovery liquors and dirty condensates to prevent sudden peaks of loading and occasional upsets in the external effluent treatment plant.
- In addition to process-integrated measures, primary treatment and biological treatment is considered BAT for kraft pulp mills.

Best available techniques for kraft pulp mills for reducing emissions to air are:

- Collection and incineration of concentrated malodorous gases and control the resulting SO2 emissions. The strong gases can be burnt in the recovery boiler, in the lime kiln or a separate, low NOx furnace. The flue gases of the latter have a high concentration of SO2 that is recovered in a scrubber.
- Diluted malodorous gases from various sources are also collected and incinerated and the resulting SO2 controlled.
- TRS emissions of the recovery boiler are mitigated by efficient combustion control and CO measurement.

- TRS emissions of the lime kiln are mitigated by controlling the excess oxygen, by using low-S fuel, and by controlling the residual soluble sodium in the lime mud fed to the kiln.
- The SO2 emissions from the recovery boilers are controlled by firing high dry solids concentration black liquor in the recovery boiler and/or by using a flue gas scrubber.
- BAT is further the control of NOx emissions from the recovery boiler (i.e. ensuring proper mixing and division of air in the boiler), lime kiln and from auxiliary boilers by controlling the firing conditions, and for new or altered installations also by appropriate design.
- SO2 emissions from auxiliary boilers are reduced by using bark, gas, low sulphur oil and coal or controlling emissions with a scrubber.
- Flue gases from recovery boilers, auxiliary boilers (in which other biofuels and/or fossil fuels are incinerated) and lime kiln are cleaned with efficient electrostatic precipitators to mitigate dust emissions.

Best available techniques for sulfite pulp mills are considered to be:

- Dry debarking of wood.
- Increased delignification before the bleach plant by extended or modified cooking.
- Highly efficient brown stock washing and closed cycle brown stock screening.
- Effective spill monitoring containment and recovery system.
- Closure of the bleach plant when sodium based cooking processes is being used.
- TCF bleaching.
- Neutralizing of weak liquor before evaporation followed by re-use of most condensate in the process or anaerobic treatment.
- For prevention of unnecessary loading and occasionally upsets in the external effluent treatment due to process cooking and recovery liquors and dirty condensates sufficiently large buffer tanks for storage are considered as necessary.
- In addition to process-integrated measures, primary and biological treatment is considered BAT for sulphite pulp mills.

Best available techniques for sulfite pulp mills for reducing emissions to air are:

- Collection of concentrated SO2 releases and recovery in tanks with different pressure levels.
- Collection of diffuse SO2 releases from various sources and introducing them in the recovery boiler as combustion air.
- Control of SO2 emissions from the recovery boiler(s) by use of electrostatic precipitators and multi-stage flue gas scrubbers and collection and scrubbing of various vents.
- Reduction of SO2 emissions from auxiliary boilers by using bark, gas, low sulfur oil and coal or controlling S emissions.
- Reduction of odorous gases by efficient collection systems.
- Reduction of NOx emissions from the recovery boiler and from auxiliary boilers by controlling the firing conditions.
- Cleaning of the auxiliary boilers flue gases with efficient electrostatic precipitators to mitigate dust emissions.

- Emission optimized incineration of residues with energy recovery.

Best available techniques for mechanical pulp mills are considered to be:

- Dry debarking of wood.
- Minimization of reject losses by using efficient reject handling stages.
- Water recirculation in the mechanical pulping department.
- Effective separation of the water systems of the pulp and paper mill by use of thickeners.
- Counter-current white water system from paper mill to pulp mill depending on the degree of integration.
- Use of sufficiently large buffer tanks for storage of concentrated wastewater streams from the process (mainly for CTMP[3]).
- Primary and biological treatment of the effluents and in some cases also flocculation or chemical precipitation.

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 is 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-deinked 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-deinked 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.

Best available techniques for papermaking and other processes 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.

[3] Chemithermomechanical pulp.

- 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.

BAT for auxiliary boilers 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 CO_2.
- Control of NO_x emissions from auxiliary boilers by controlling the firing conditions, and installation of low-NOx burners.
- Reducing SO_2 emissions by using bark, gas or low sulphur fuels or controlling S emissions.
- In auxiliary boilers burning solid fuels efficient ESPs (or bag filters) are used for the removal of dust.

Table A1: Emissions Levels to Air and Water Associated with Best Available Techniques. Emissions levels are yearly averages and standard conditions (From European Commission. 2001).

Process or product[4]	Flow m^3/Adt [5]	COD kg/Adt	BOD kg/Adt	TSS kg/Adt	AOX kg/Adt	Total N kg/Adt	Total P kg/Adt	Dust kg/Adt	SO_2 kg/Adt [6]	NO_x kg/Adt [7]	TRS kg/Adt [8]
Kraft[9] bleached pulp	30-50	8-23	.3-1.5	.6-1.5	< .25	.1-.25	.01-.03	.2-0.5	.2-.4	1-1.5	.1-.2
Kraft unbleached pulp	15-25	5-10	.2-.7	.3-1	-	.1-.2	.01-.02	.2-.5	.2-.4	1-1.5	.1-.2
Sulphite bleached pulp	40-50	20-30	1-2	1 -2	-	.15-.5	.02-.05	.02-.15	.5-1	1-2	-
Non-integrated CTMP[10]	15-20	10-20	.5-1	.5-1	-	.1-.2	.005-.01	-	-	-	-
Integrated mechanical pulp & paper[11]	12-20	2 -5	.2-5	.2-.5	<.01	.04-.1	.004-.01	-	-	-	-
Integrated RCF[12] paper mills without deinking	<7	.5-1.5	<.05-.15	.05-.15	<.005	.02-.05	.002-.005	-	-	-	-
RCF paper mills with de-inking	8-15	2-4	<.05-.2	.1-.3	<.005	.05-.1	.005-.01	-	-	-	-
RCF based tissue mills	8-25	2-4	<.05-.5	.1-.4	<.005	.05-.25	.005-.015	-	-	-	-

[4] The figures reported here are for production only; they do not include emissions from auxiliary boilers or power plants. Those figures are reported separately in Table 3.
[5] Air Dried Ton (ADT) for pulp and tonne for paper product.
[6] As S.
[7] $NO+NO_2$ as NO_2.
[8] Total Reduced Sulphur (TRS) as S.
[9] Figures are for pulp production only.
[10] Contribution of Chemi-thermo-mechanical pulping only and reported per tonne of paper produced.
[11] Figures are for pulping and papermaking and reported per tonne of paper produced.
[12] Recycled fibres (RCF) and reported per tonne of paper produced.

Uncoated fine paper	10-15	.5-2	.15-.25	.2-.4	<.005	.05-.2	.003-.01	-	-	-	-
Coated fine paper	10-15	.5-1.5	.15-.25	.2-.4	<.005	.05-.2	.003-.01	-	-	-	-
Tissue	10-25	.4-1.5	.15-.4	.2-.4	<.01	.05-.25	.003-.015	-	-	-	-

Table A2: Heat and Power Consumption Associated with Best Available Techniques (From European Commission. 2001).

Process or Product	Process Heat (GJ/Adt)	Power (MWh/Adt)
Non-integrated bleached kraft pulp mills	10-14	.6-.8
Integrated bleached kraft pulp and paper mills	14-20	1.2-1.5
Integrated unbleached kraft pulp and paper	14-17.5	1-1.3
Integrated sulphite pulp and paper mills	24	1.2-1.5
Non-integrated CTMP[13]	-	2-3
Integrated newsprint mills	0-3	2-3
Integrated LWC[14] paper mills	3-12	1.7-2.6
Integrated SC[15] paper mills	1-6	1.9-2.6
Integrated non-deinked RCF paper mills	6-6.5	.7-.8
Integrated tissue mills with DIP[16] plant	7-12	1.2-1.4
Integrated newsprint or printing and writing paper mills w/ DIP plant	4-6.5	1-1.5
Non-integrated uncoated fine paper mills	7-7.5	.6-.7
Non-integrated coated fine paper mills	7-8	.7-.9
Non-integrated tissue mills based on virgin fibre	5.5-7.5	.6-1.1

[13] Chemi-thermo-mechanical pulp.
[14] Lightweight coated (higher grade wood-containing graphic papers).
[15] Supercalendered paper.
[16] Deinked pulp.

Table A3. BAT Associated Emission Levels from Auxiliary Boilers in Pulp and Paper Industry that Incinerate Different Kinds of Fuels. (From European Commission. 2001)

Released substances	Coal	Heavy fuel oil	Gas oil	Gas	Biofuel (e.g. bark)
mg S/MJ fuel input	100-200 [1] (50-100)[5]	100-200 [1] (50-100)[5]	25-50	< 5	< 15
mg NO_x/MJ fuel input	80-110 [2] (50-80 SNCR)[3]	80- 110 [2] (50–80 SNCR)[3]	45-60 [2]	30-60 [2]	60-100 [2] (40-70 SNCR)[3]
mg dust/Nm^3	10- 30 [4] at 6% O_2	10- 40 [4] at 3 % O_2	10-30 3% O_2	< 5 3% O_2	10-30 [4] at 6% O_2

Notes:

1) Sulphur emissions of oil or coal fired boilers depend on the availability of low-S oil and coal. Certain reduction of sulphur could be achieved with injection of calcium carbonate.
2) Only combustion technology is applied
3) Secondary measures as Selective Non-Catalytic Reduction (SNCR) are also applied; normally only larger installations
4) Associated values when efficient electrostatic precipitators are used
5) When a scrubber is used; only applied to larger installations