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Environmental Pressure Information System (EPIS) for the Pulp and Paper Industry in Norway

Contents

1. Background

The development of the Environmental Pressure Information System, EPIS, originates from needs for timelier data on environmental pressures from human activities. The objective of EPIS is to provide a tool for the compilation of timely and harmonised data on environmental pressure arising from different economic activities. Accordingly, EPIS will contribute to the production of pressure indicators and indices, indicators of sustainable development (e.g. efficiency indicators), to compilation of statistics on material flows and cumulative pressures as well as to the NAMEA Environmental Accounting (Eurostat 1999).

The objective of EPIS is to compile data in a format that provides a link between environmental pressures and economic activity in the way that is most useful for comprehensive material flow assessment and for those engaged in economic-environmental decision making research (Eurostat 1999).

The EPIS approach takes as its starting point the conventional material balance approach; the inputs of materials and energy to one process are in balance with the system accumulation and outputs of the products and residuals arising from the same process in a given time period (Eurostat 1999).

Different countries have done several pilot studies. The Norwegian pilot studies have been focused at the compilation of pressure coefficients. Material flow approaches have been made for the Norwegian offshore oil and gas production (Rypdal and Tornsjø 1999). Recently a Norwegian project on chemicals in EPIS has been performed (Rypdal and Tornsjø 2000).

2. Project objectives

2.1. Objectives

The aim of this part of the EPIS project is to establish an EPIS for the Norwegian wood-processing industry. The EPIS database relies on the material flow approach, where inputs of material and energy to one process are in balance with the system accumulation and output of products and residuals arising from the same process in a given period. The data will be based on available statistics. The wood processing industry uses a lot of raw material and has considerable emissions to air and discharges to water.

2.2. Norwegian wood-processing industry

In 1998 the wood-processing industry in Norway accounted for 23 per cent of the total national SO_2 emissions from stationary combustion and 3 per cent of CO_2 emissions (Statistics Norway 1999a). The industry accounted for about 0.4 per cent of GDP in 1997 and 0.5 per cent in 1998 (National Accounts).

In 1997, 1,566,000 tonnes mechanical pulp and 684,000 tonnes chemical pulp (sulphate pulp and sulphite pulp) was manufactured in Norway, according to the Industry Statistics in Statistics Norway. Mechanical pulp accounted for nearly 70 per cent of the total pulp production.

The structure of Norwegian pulp and paper industry in 1997, according to the data available from the Industry Statistics in Statistics Norway, is given in table 2.1. Some of the mills exist no longer today. The mills that existed in 1997 are included in the balance. Several of the mills are integrated i.e. produce both pulp and paper. The paper industry invests the most in plant and equipment for environmental protection and emissions reduction. Almost 18 per cent of the paper industry's total investments in 1997 went to environment protection activities (Statistics Norway 1999b).

Table 2.1. The structure of Norwegian pulp and paper industry 1997.

	Number of mills
Mechanical pulp	13
Chemical pulp/Semi-chemical	4
Paper and board	18

Source: Industry Statistics, Statistics Norway

There is no new literature on description of processes in the pulp and paper industry in Norway. The industry has, and still is, going through technical and structural changes. As the pulp and paper industries in Norway are assumed to be very like those in Finland, a Finnish report (The Finnish Ministry of the Environment 1997) has been used to describe the different processes in Norway.

Recently an international project on assessment of life-cycle wide energy related environmental impacts in the pulp and paper industry has been performed (Institute for Energy Technology, IFE, 1999b). The project has formally been carried out in auspices of the International Energy Agency. A new standard for calculation and reporting of specific energy use and also boundaries for carrying out life-cycle analyses on energy products for pulp and paper production are proposed in the project. Specific energy use is an important factor for benchmarking purposes. Examples of calculations of specific energy use for different type of plants are given in the report. In this work energy coefficients per branch is to be identified, and therefore it will be difficult to compare these factors with the ones in IFE (1999b).

3. Nomenclature and data sources

3.1. Codes of interest

Sectors of interest are:

NACE 21.111 Manufacture of mechanical pulp
NACE 21.112 Manufacture of chemical processed pulp
NACE 21.12 Manufacture of paper and paperboard

NOSE-P codes of relevance for these sectors are:

101.01	Combustion plants >=300 MW (boilers)
101.02	Combustion plants >= 50 and <300 MW (boilers)
104	Characteristic processes in manufacturing industry, involving fuel combustion
104.07	Characteristic processes in the manufacture of pulp, paper and paper products, publishing and printing
104.07.01	Drying processes in paper mills
105	Production processes in manufacturing industry, not involving fuel combustion
105.07	Characteristic processes in the manufacture of pulp, paper and paper products, publishing and printing
105.07.01	Paper pulp (kraft process)
105.07.02	Paper pulp (acid sulfite process)
105.07.03	Paper pulp (Neutral Sulphite Semi - Chemical process)
105.07.04	Mechanical pulping
105.07.05	Paper processing
105.07.06	Lime sludge reburning kilns
105.07.07	Soda recovery boilers
105.07.08	Processing of waste paper and paperboard
105.07.11	Production of paper and paperboard
105.14.26	Recovery of paper paperboard

109	Pollution control, treatment and waste disposal
109.01	Air-pollution control processes
109.02.31	Processing and fermentation of industrial sludge
109.02.41	Wastewater treatment in industry

It will be difficult to use several of the NOSE-codes as data at such detailed level not are available or cannot be used due to confidentiality rules. In another EPIS work, concerning NOSE, we have tested the NOSE nomenclature on the Norwegian Pollution Control Authority's pollution register, INKOSYS. The register contains information about emissions to air, discharges to water and waste generated from about 1000 plants in Norway.

In the Norwegian national model for calculation of air emissions, the following codes are used:

1 Stationary combustion
103 Industry
1032 Wood-processing industry

2 Process emissions
203 Wood-processing industry

3.2. Energy- and emission data

Energy data for the three processes (NACE 21.111, 21.112 and 21.12) are available from an annual survey by the Industry Statistics in Statistics Norway. Consumption of wood, wood waste and black liquor from this industry is however only available from the Institute for Energy Technology (1999a). These data are also used in the energy accounts and in the Norwegian emission inventory, as these energy commodities not are included in the survey by the Industry Statistics. Emission data are available from the Norwegian emission inventory, which includes emissions from stationary combustion and from processes in the wood-processing industry. Some of the wood-processing plants are considered as point sources in the inventory. Emissions of SO_2 from these plants are available from INKOSYS, a register administered by the Norwegian Pollution Control Authority (SFT). Almost all the wood-processing plants in Norway have to report their emissions to air and discharges to water to the SFT annually. Only the emission data for SO_2 from INKOSYS are used in the emission inventory as they are considered to be more correct than calculated values. The specific conditions at each plant concerning sulphur content of the fuel, various cleaning equipment etc. will be considered in the reported data.

4. Methodology

The EPIS database relies on the material flow approach, where inputs of material and energy to one process are in balance with the system accumulation and output of products and residuals arising from the same process in a given period. Material balances for each of the three NACE sectors of interest in this work are prepared. There is made an attempt to make figures of each of the material flow characteristic to more easily get the view of what are to be included as input and output in the processes. Input and output data are based on available statistics. Descriptions of the processes in each of the sectors are given and from input- and output data for each process coefficients related to tonne product produced have been calculated.

5. Results for manufacture of mechanical pulp

5.1. General

The main constituents of wood are carbohydrates and lignin. In the carbohydrate group, the polymer cellulose, is the backbone of the trees. Cellulose forms fibres, which are glued together with lignin, forming a light and strong wooden structure. The fibres can be formed into sheets with the aid of water. For most pulping processes the bark has to be removed. The debarking of logs is done mechanically, using water for washing and in wintertime for de-icing. Wood residues from sawmills, sawmill chips, are utilised as fibre raw material in chemical and mechanical pulping (The Finnish Ministry of the Environment 1997) or as fuels.

There are two types of mechanical pulp, groundwood and refiner pulp. In Norway today refiner pulp is the dominating mechanical pulp. In mechanical pulping the wood fibres are separated from each other by mechanical energy. The yield in mechanical pulping is high, about 92-97 per cent (The Finnish Ministry of the Environment 1997).

5.2. Process description

Groundwood pulp

In the conventional groundwood process debarked wood logs are pressed against a grinding stone in a grinder at atmospheric pressure. The mechanical work is mainly transformed into heat and the temperature of the wood rise. The lignin softens and the bonds holding the individual fibres together weaken. High amount of shower water is used. Grinder-based pulps are divided into different types on the basis of the grinding pressure and the shower temperature (The Finnish Ministry of the Environment 1997).

The process has a high use of external energy. Water pollution is modest. Air pollution depends on the fuel used in the generation of external energy.

Refiner pulp

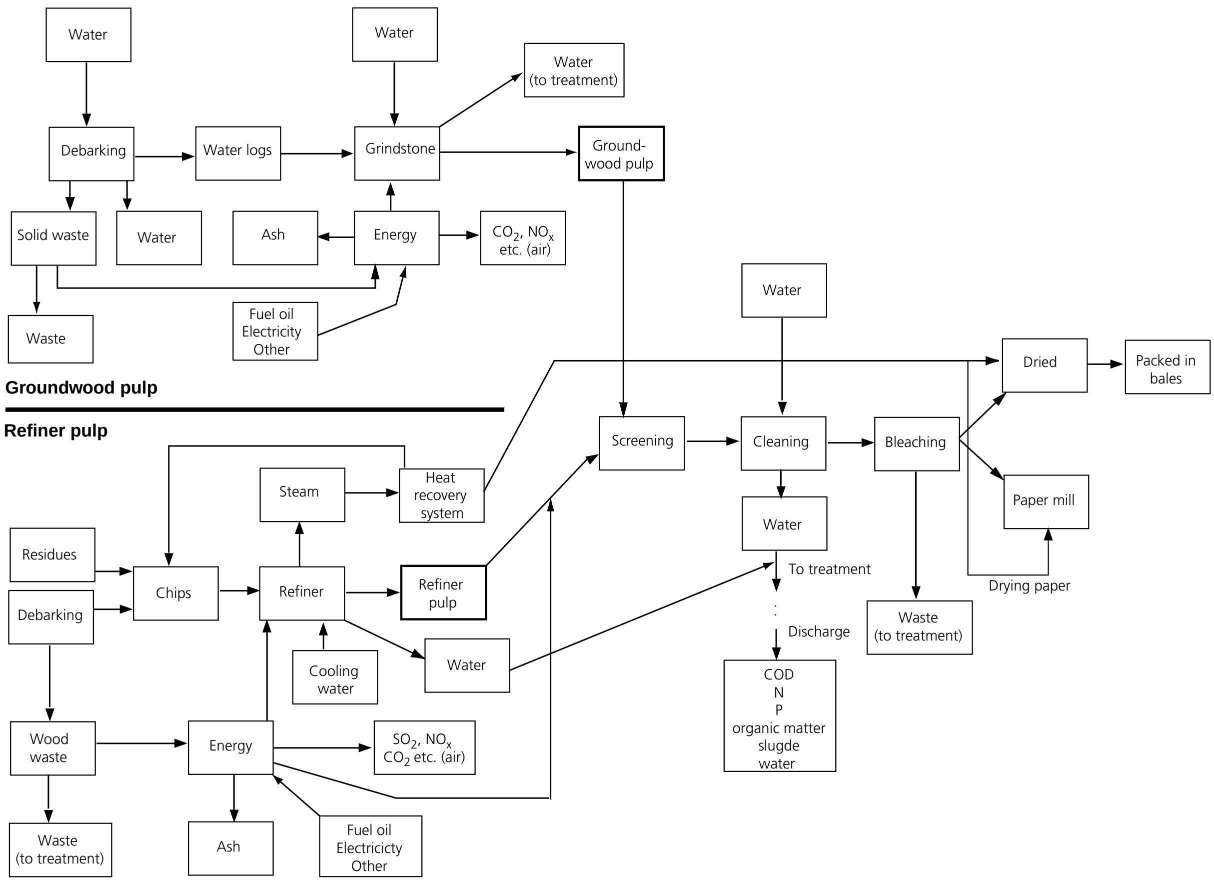
In refiner mechanical pulp, chips are ground between steel discs with bar patterns in a refiner. The forces from the impact of the bars cause the chips to break down into fibre bundle, individual fibres and fibre fragments. Most of the energy applied (friction work) transforms into heat which flashes part of the moisture in the chips. To prevent the wood from burning in the refining zone, cooling (dilution) water has to be added. The large quantity of steam released in the refining process is normally captured in a heat recovery system for further use (The Finnish Ministry of the Environment 1997).

After the mechanical pulp is screened, cleaned, bleached if necessary, it is pumped to the paper mill if integrated or is dried and packed in bales. The bleaching of mechanical pulp aims at changing cromoforic groups in the lignin into a colourless form without causing a yield loss. There are two main chemicals used in the bleaching, sodium dithionite ($Na_2S_2O_4$) and hydrogen peroxide (H_2O_2). Other chemicals are also needed for e.g. give the pH environment required (The Finnish Ministry of the Environment 1997).

The characteristics of the pulp can be affected by increasing the processing temperature and by the chemical treatment of the chips before entering the refiner. Two kinds of refiner pulp are made in Norway, thermo mechanical pulp (TMP) and chemi thermo mechanical pulp (CTMP). The two processes are very similar.

The majority of the Norwegian production of mechanical pulp is integrated with the production of paper. An attempt to make a material flow characteristic for manufacturing of mechanical pulp is given in figure 5.1. In the Industry Statistics the companies are classified according to the main business, which means that an integrated plant that produces pulp for manufacture of paper and not for sale, will be classified as branch 21.12 'Manufacture of paper and paperboard' and not 21.111 'Manufacture of mechanical pulp'. In this work integrated plants are classified as 21.111, as the emissions in most cases are connected to the pulp part.

Figure 5.1. Material flow characteristics for production of mechanical pulp



5.3. Material flow characteristics

5.3.1. Input

Raw material and operating substances

The only data available on use of raw material is from 1993 (Raw material survey 1993). Estimation of use of raw material in 1997 have been carried out based on raw material data from 1993 and production data. This will contribute to the uncertainty of the coefficients. Surveys which aims to register the use of raw material in the industries are carried out regularly, approximately every 4th year, by the Industry Statistics in Statistics Norway. Data for 1997 will be available early in year 2000. The data is given for the main business for a company, e.g. if a company has several different businesses, the raw material is specified for the main business. This will only be a problem if a wood-processing company also runs other businesses, which have higher sales than the wood-processing company.

The best wood raw material for mechanical pulping processes is spruce and aspen. Norwegian spruce is one of the best raw materials for both refining and grinding (The Finnish Ministry of the Environment 1997). Spruce and other conifers are the dominating raw materials in the Norwegian wood-processing industry according to the Industry Statistics for 1993. Chip from saw mills are also used as raw material.

Not very large amounts of chemicals are used in the production of mechanical pulp. Sodium dithionite, sodium sulphite, sodium hydroxide and hydrogen peroxide are used for bleaching (EPIS 1999).

Most of the plants classified as NACE 21.111 in the statistics for use of raw materials are classified as NACE 21.12 in the production statistics. It indicates that the majority of the Norwegian production of mechanical pulp is integrated with the production of paper. The raw materials used are divided into integrated and non-integrated plants respectively. Table 5.1 shows the estimated use of raw materials and operating substances (mainly chemicals) per tonne product produced.

The total pulp produced in integrated plants is not included as input to avoid double counting of the pulp. Only pulp produced for sale and paper produced are to be regarded as the products in the balance. According to the Industry Statistics there were no sale of pulp produced in integrated plants in 1997. It is assumed that all the pulp produced at the integrated plants is used as raw material in the plants.

The total pulp produced in the integrated plants in 1997 is about 285 ktonnes less than the estimate of pulp used as raw material for manufacturing of paper in integrated plants. Some of the difference may be due to pulp purchased. But there has been an increase in the use of waste/recycled paper as raw material since 1993. It was an increase in the import of pulp, and paper and board for recycling to Norway from 1993 to 1997, according to statistics for external trade. More use of waste/recycled paper as raw material in 1997 compared to 1993, may also be an explanation for the difference seen. The estimate of pulp used as raw material seems to be to high, but it is used in lack of other data.

Kaolin is used only in the paper production. Kaolin is a type of pigment, which is used as raw material in paper production to among others give the paper an even and brighter surface (Norske Skog 1999). It is included in pulp, waste paper and board in table 5.1.

Table 5.1. Raw materials (including chips) and operating substances per tonne product produced. 1997

	Integrated plants[1]	**Non-integrated plants**[2]	**Sweden**[3]
Raw material (m^3/tP)	1.9	2.1	2.4 - 2.8
Pulp, waste paper and board (kg/tP)[4]	333	-	-
Operating substances (kg/tP)	33	44	-

[1] The values refer to paper produced, since there was no sale of pulp produced at integrated mills in 1997.
[2] The values refer to pulp produced.
[3] Type of products is not specified in the Swedish work.
[4] Kaolin is included.
Source: Industry Statistics, Statistics Norway and EPIS (1999).

The use of chemicals in non-integrated plants is higher compared to integrated plants. This is mainly due to the production of chemi-thermo mechanical wood pulp (CTMP). None of the integrated plants produce that kind of mechanical pulp according to the Industry Statistics.

The Norwegian coefficient for use of raw material for non-integrated plants is almost the same as the factor interval given in the Swedish EPIS work (EPIS 1999), while the factor for integrated plants is lower compared to the Swedish values.

Energy
The wood-processing industry is an energy demanding industry. In 1997 it accounted for about 14 per cent of the total use of electricity in the manufacturing industries (Energy Statistics).

Electric power is used to power refiners and grinding stones. The large quantity of steam released in the refining process is normally captured in a heat recovery system for further use such as drying the final product. Mechanical pulping has high use of external energy compared to chemical pulping, which has limited use of external energy and modern mills produce net energy. The specific energy consumption in mechanical pulping is dependent on the pulping process, the properties of the raw material and to a large extent the quality demands on the pulp set by the end product (The Finnish Ministry of the Environment 1997). The wood-processing industry has high flexibility regarding use of oil/electricity. The type of energy commodity used may vary considerably from one year to another and during a year dependent on the price of electricity.

Energy data for each plant are available from the Energy Statistics in Statistics Norway (SN) since the wood-processing plants report their energy use to SN annually. Consumption of wood, wood waste and black liquor is however only available from the Institute for Energy Technology, IFE (1999a). The same data are also used in the energy accounts and in the Norwegian emission inventory, as these energy commodities not are included in the survey by SN. The energy used per tonne of product is given in table 5.2 for integrated and non-integrated plants respectively. Factors from the Swedish EPIS work (EPIS 1999) are also shown in the table for comparison. Coal is included in the category fuel oils in the table due to confidentiality reasons. The plants do not specify ’other’, but according to IFE it may include biofuels, waste paper, sludge etc.

Table 5.2. Energy used per tonne product produced in integrated and non-integrated plants. 1997. GJ/tP

Energy type	Integrated[1]		Non-integrated	
	Norway	Sweden	Norway[4]	Sweden
Total	14.0	13.3 (TMP/newsprint) 14.5 (other integrated)	10.5	7.9
Wood, wood residues and black liquor	2.2	2.9 (TMP/newsprint) 2.6 (other integrated)	1.0	1.7
Fuel oil[2]	1.4	1.7 (TMP/newsprint) 3.8 (other integrated)	3.1	1.4
Electricity	10.2	2.7 (TMP/newsprint) 1.1 (other integrated)	6.3	1.8
Process heat	(2.3)[5]	6 (TMP/newsprint) 7 (other integrated)	:	3
Other[3]	0.2		:	

Not for publication :

[1] GJ/tonne paper produced. There was no sale of pulp produced in integrated plants in 1997.
[2] Coal is included due to confidentiality reasons.
[3] Other, not specified.
[4] GJ/tonne pulp produced.
[5] Not included in total due to double counting of fuel.
Source: Energy Statistics, Statistics Norway, Institute for Energy Technology (1999a) and EPIS (1999).

The factors for total use of energy given in the table shows that integrated plants in Norway lie in the interval of the Swedish factors, while non-integrated plants in Norway have somewhat higher factor than Sweden. The Norwegian factors for wood, wood residues and black liquor are lower than the Swedish factors. The factors for electricity are higher in Norway than in Sweden, which most likely is caused by more use of electricity in this industry in Norway due to lower prices. As mentioned above, the fraction of use of electricity may vary from year to year dependent on the price of electricity.

Water
Large amounts of water are used in the process. There are no data available.

The main wood-processing company in Norway informs in their annual report that the total use of process water in their plants is about 60 mill.m^3, but the company's plants abroad are also included in the figure.

In the Swedish EPIS work a factor of > 15 m^3 process water/tP (TMP/newsprint) is given. This factor is in this work used for the integrated plants due to lack of other data.

5.3.2. Output

Main product

Production of pulp for sale and the production of paper are to be regarded as the main products from integrated plants. There was no sale of pulp produced in integrated plants in 1997 according to the Industry Statistic. It is assumed that all the pulp produced at integrated plants is used as raw material. There is a possibility that some of the pulp may be kept as stock however.

Total production of paper, newsprint, etc. (PRODCOM 21.12), for the integrated plants was 1796 ktonnes in 1997 according to the Industry Statistics, and the production of pulp in non-integrated plants was 172 ktonnes.

One of the integrated plants is also producing chemical pulp in addition to mechanical pulp and paper. The plant is defined as an integrated plant with NACE 21.111 in the material balance.

Wastewater

The production of mechanical pulp gives discharges of oxygen demanding compounds, COD and BOD. There are also some emissions of phosphorus and nitrogen. The discharge of nitrogen originates from wood and chelating agents (e.g. EDTA) used in bleaching. The discharge of phosphorus depends on the wood (The Finnish Ministry of the Environment 1997).

The discharges of COD, phosphorous, nitrogen, suspended dry matter, organic suspended matter, water and oil are given in INKOSYS, which is a register administered by the Norwegian Pollution Control Authority. The amounts of water and oil are only reported by one plant and can not be used due to confidentiality reasons.

An average factor for discharges of wastewater per tonne product from the pulp and paper plants is given in the annual report from the main wood-processing company in Norway (Norske Skog 1999). This factor was 25 m^3 wastewater/tonne product for 1997. As mentioned above, plants abroad are also included in this figure. Production abroad accounts for about 24 per cent of the company's total production (estimate from figures given in Norske Skog 1998). If the average factor is used to calculate discharges of wastewater for all the plants in branch 21.111 in Norway, it gives a discharge of about 45 mill.m^3. Since this figure is quite uncertain, it will not be included in the balance.

In the Swedish EPIS work a factor of 15 m^3 effluent (wastewater)/tP (TMP and newsprint) is given (EPIS 1999). This factor is used for the integrated plants due to lack of other data.

Waste

The solid primary waste removed from the mechanical pulping processes consists of bark and wood residues from the debarking, fibre rejects, ash from energy production and sludge from external waste water treatment (The Finnish Ministry of the Environment 1997). When a paper mill is included there also could be included waste paper and residues of coating from the process finishing the paper. Environmental hazardous waste mainly consists of grease and oil from the lubrication of the machinery. There are also some residues of solvents and paint and small quantities of chemicals from the process (EPIS 1999).

Amounts of industrial waste in Norway are given from a survey by Statistics Norway (Statistics Norway 1998). The survey gives data for waste and special waste generated in 1996. The only concern is that the data for pulp, paper, paper products and publishing are all in the same group. We have had a closer look at the individual data trying to extract some more information (table 5.3). The estimation done is very rough and the figures have high uncertainty. A further distribution of the waste generated in the different classes like mechanical pulp, chemical pulp and integrated versus non-integrated plants will be difficult and the result very uncertain.

Table 5.3. Rough estimation of production and special waste in pulp and paper producing industries. 1996. ktonnes

Branch	**NACE**	**Wood waste**	**Paper and paperboard waste**	**Ash**	**Sludge**	**Special waste[1], tonne**
Total		150-200	78-110	20	80	90
Manufacture of pulp	21.111+ 21.112	150-200	8-10	15	80	65
Manufacture of paper	21.12	-	70-100	5	-	25

[1] Include wastes containing heavy metals, acids, bases and other organic- and inorganic waste.
Source: Estimation based on waste statistics from 1996.

Factors for total waste in mechanical pulping given in the Swedish EPIS work:
128 kg/tP (non-integrated)
117 kg/tP (other integrated)

By using these factors, total waste generated from integrated and non-integrated plants in Norway is estimated (table 5.4). As seen in the table the total waste generated from integrated plants in Norway will be about 210 ktonnes and 22 ktonnes from non-integrated plants using the Swedish factors. If the different types of waste in table 5.3 are added up for the branches 21.111 and 21.112, an interval of 318-370 ktonnes total waste is obtained. From table 5.4 it can be seen that a value of about 230 ktonnes total waste is obtained for the branch 21.111 when using the Swedish factors. This value, including the branch 21.111 only, is lower than the Norwegian estimates, which include both 21.111 and 21.112. This comparison may indicate that the Norwegian estimates may be reliable. But the estimates cannot be split into such a detailed level of NACE needed and further into waste generated from integrated and non-integrated plants. It is therefore chosen to use the Swedish factors in the balance, but the Swedish factors do not say anything about the type of waste generated as the Norwegian estimates do.

Table 5.4. Estimation of waste generated in Norway using the Swedish factors. 1996. ktonnes

Branch 21.111	**Waste, total**
Non-integrated	22
Integrated	210

Air emissions

Emissions of CO_2, CH_4, N_2O, particulate, NO_x, SO_2, NMVOC, CO, Pb and Cd are given in the emission inventory from Statistics Norway and Norwegian Pollution Control Authority. As mentioned earlier, the SO_2 emissions from some plants are available from the Norwegian Pollution Control Authority.

Due to confidentiality, the figures of SO_2 emissions from non-combustion processes have to be included in the figures for emissions from combustion. Table 5.5 shows the emissions per tonne product. Non-integrated plants have generally higher emissions per product than integrated plants for all the components, except for methane and NMVOC.

Table 5.5. Emissions per tonne of product. Mechanical pulping. 1997. kg/tP

	SO_2	NO_x	CO_2	CH_4	N_2O	NMVOC	Particulate
Non-integrated	0.92	0.43	246	0.02	0.01	0.10	0.09
Integrated	0.53	0.29	109	0.04	0.01	0.16	0.07

Source: Norwegian emission inventory, Statistics Norway and Norwegian Pollution Control Authority.

A comparison between Norwegian and Swedish factors cannot be done since such factors not are given in the Swedish EPIS work.

5.4. Overview results

Table 5.6 shows an overview of the material flow characteristics for production of mechanical pulp. The factors are given per pulp and paper produced. The difference between input and output is -203 kg/tP for non-integrated plants and 216 kg/tP for integrated plants. The differences seen are most likely due to uncertainty concerning the water flow, the input of raw material and waste generated. The Swedish factor of > 15 m^3/tP which is used on the input side does not give an interval for how much water that is used. The same factor is also used on the output side. Since the wood-processing industry has a high water demand this will be a serious lack in the balance. Data on use of raw material are estimated from data on use of raw material from 1993 and the change in production. It is also important to note that the factors for waste generated is somewhat uncertain as they mainly apply for Swedish conditions.

Table 5.6. Material flow characteristics for mechanical pulp production

INPUT	Unit	Value	Value, kg/tP
Energy carriers (non-integrated)			
- Wood and residues	GJ/tP	1.0	62
- Fuel oils[1]	GJ/tP	3.1	77
- Other	GJ/tP	:	
- Process heat	GJ/tP	:	
- Electric power	GJ/tP	6.3	
Energy carriers (integrated)			
- Wood and residues	GJ/tP	2.1	135
- Fuel oils[1]	GJ/tP	1.4	35
- Other	GJ/tP	0.2	
- Process heat[2]	GJ/tP	(2.3)	
- Electric power	GJ/tP	10.2	
Raw materials and operating substances			
Raw materials	m^3/tP (non-integrated)	2.1	1037
	m^3/tP (integrated)	1.9	943
Pulp, waste paper and board[3]	kg/tP (integrated)		333
Operating substances	kg/tP (non-integrated)		44
	kg/tP (integrated, pulp/paper)		33
Water			
Process water[4]	m^3/tP (TMP/newsprint)	>15	> 15000
Cooling water	kg/tP		
OUTPUT			
Product	tP	1	1000
Byproduct	kg/tP		-

Wastewater			
Process water[4]	m^3/tP (integrated)	15	15000
Cooling water	kg/tP		..
COD	kg/tP (non-integrated)		40
	kg/tP (integrated)		32
BOD	kg/tP		..
tot-N	kg/tP (non-integrated)		0.66
	kg/tP (integrated)		0.27
tot-P	kg/tP (non-integrated)		0.08
	kg/tP (integrated)		0.04
Suspended organic matter	kg/tP (integrated)		2.0
Suspended dry matter	kg/tP (non-integrated)		5.7
	kg/tP (integrated)		1.0
Waste			
- Waste (total) [4]	kg/tP (non-integrated)		128
- Waste (total) [4]	kg/tP (integrated)		117
- Production waste	kg/tP		..
- Hazardous waste	kg/tP		..
- Sludge	kg/tP		..
- Waste from energy production	kg/tP		..
Air emissions	kg/tP		
- SO_2	kg/tP (non-integrated)		0.92
	kg/tP (integrated)		0.53
- NO_x	kg/tP (non-integrated)		0.43
	kg/tP (integrated)		0.29
- CO_2	kg/tP (non-integrated)		246
	kg/tP (integrated)		109
- CH_4	kg/tP (non-integrated)		0.02
	kg/tP (integrated)		0.04
- N_2O	kg/tP (non-integrated)		0.01
	kg/tP (integrated)		0.01
- CO	kg/tP (non-integrated)		1.0
	kg/tP (integrated)		1.7
- NMVOC	kg/tP (non-integrated)		0.10
	kg/tP (integrated)		0.16
- Pb	kg/tP (non-integrated)		0.00007
	kg/tP (integrated)		0.00003
- Cd	kg/tP (non-integrated)		0.00001
	kg/tP (integrated)		0.00002
- Dust	kg/tP (non-integrated)		0.09
	kg/tP (integrated)		0.07
Difference input - output	*non-integrated*		*-203*
	integrated		*216*

Data not available .. Not for publication :
[1] Include: heating oil, heavy distillate, heavy oil and coal.
[2] Double counting of fuel.
[3] Include kaolin.
[4] Swedish factors (EPIS 1999).

6. Results for manufacture of chemical processed pulp

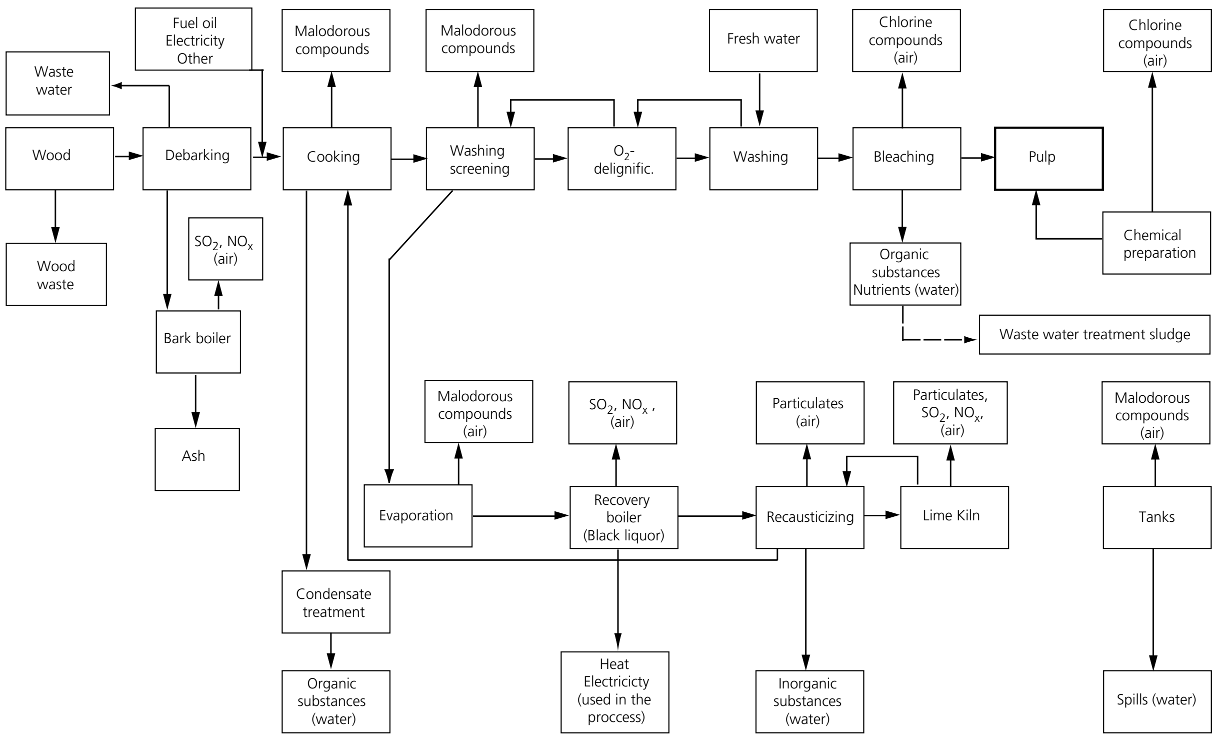
6.1. General

In chemical pulping process the fibres are liberated from the wood matrix as the lignin is removed by dissolving in the cooking chemical solution at a high temperature. Chemical pulp is manufactured by two main pulping processes, the sulphite process and the sulphate or kraft pulping process. In the sulphite process the cooking chemical is bisulphite or sulphite, and in the kraft pulp process the cooking chemicals are sodium hydroxide and sodium sulphide (The Finnish Ministry of the Environment 1997). Today kraft pulping is the dominant process throughout the world for manufacturing chemical pulp. The use of the sulphite process has been steadily decreasing. As shown in table 2.1, there were 4 chemical pulp mills in Norway in 1997, two of them were integrated. One of the plants also produced mechanical pulp and paper in addition to chemical pulp. This plant is included in the balance for integrated mechanical pulp plants. Since there therefore only are three plants left in this category, NACE 21.112, it will be some difficulties connected to the use of data due to confidentiality reasons.

6.2. Process description

A kraft pulp mill can be divided into three main parts. A conventional division is the fibre line, recovery system and external wastewater treatment. The spent liquor (black liquor) is removed in the first pulp washing stage, concentrated and burnt as fuel. The inorganic chemicals in the black liquor are recovered after combustion, regenerated into cooking chemicals and returned to cooking. The energy produced in the combustion of the organic material dissolved in the delignification is used in the process as heat and electrical energy (The Finnish Ministry of the Environment 1997). An attempt to make a material flow characteristic for manufacture of chemical pulp is shown in figure 6.1. Pulp produced for sale and paper produced, are to be regarded as the products in the balance.

Figure 6.1. Material flow characteristic for manufacturing of chemical pulp



Source: The Finnish Ministry of the Environment (1997)
It is not specified what is included in tanks.

Delignification, washing and screening
Chips of all wood and most non-wood plants are used as raw material. In the kraft process the fibres are liberated in the cooking plant by dissolving the lignin and part of the hemicelloluse in the cooking chemical solution, which contains sodium hydroxide and sodium sulphide as active chemicals. Not all lignin can be dissolved in the process. Several cooking modification methods have been developed with the aim of removing more lignin from the wood without reducing the yield during cooking. (The Finnish Ministry of the Environment 1997)

The pulp coming from the cooking contains both fibres and spent cooking liquor (black liquor). About half of the wood is dissolved in the cooking. The black liquid is removed from the pulp in the subsequent washing, and led to the chemical recovery system, where the cooking chemicals and energy are recovered. Pulp washing is important for the recovery of black liquor. Modern pulp washing facilities normally recover at least 99 per cent of the chemical applied in the digester. Typical washing losses at Finnish mills are 6-10 kg/tonnes of pulp for softwood and 8-12 kg/tonne of pulp for hardwood measured as COD_{Cr}. Before further processing, the pulp is screened in order to remove foreign particles and bundles of undesired fibres (The Finnish Ministry of the Environment 1997).

After cooking and screening, the delignification can be continued by oxygen in one or two stages with or without intermediate washing. The benefits from delignification in terms of quality are brightness stability, the removal of pitch and cleanness.

Bleaching
If it is intended to bleach the pulp, it undergoes a bleaching process. If not, the pulp is dried or if the mill is integrated, it is pumped to the paper works (EPIS 1999).

The purpose of pulp bleaching is to remove the remaining lignin and impurities in the pulp and thus obtain certain pulp quality criteria with respect to brightness, brightness stability, cleanness and strength. The bleaching of chemical pulps is carried out in several stages. Washing the pulp thoroughly follows all bleaching stages. The most commonly used chemicals are chlorine dioxide, oxygen, ozone and peroxide. Chlorine dioxide and ozone have to be produced on site. Peroxide, oxygen and alkali are delivered to the mills. The main wood company in Norway informs in their annual report that chlorine is not used for bleaching today, due to environmental reasons. It is assumed that this is valid for the whole Norwegian pulp manufacturing. Chlorine was however used in 1993 and is included in the data on raw materials, but it will not be included in the balance, as it is not used today. The main wood-processing company in Norway informs that they only use chlorine dioxide, peroxide or oxygen for bleaching today (Norske Skog 1999)

The two main types of bleaching methods are the EFC (elemental chlorine free) bleaching and the TCF (totally chlorine free) bleaching. The chemicals used in ECF bleaching are chlorine dioxide, alkali (NaOH), peroxide as well as oxygen. In TCF bleaching oxygen, ozone and peroxide are used. TCF bleaching with peroxide requires the use of metal chelating agents (e.g. EDTA) or removal of metal ions with acid to avoid degradation of hydrogen peroxide (The Finnish Ministry of the Environment 1997).

After bleaching the pulp is dried or if the mill is integrated it is pumped to the paper works. In the drying process the pulp is drained of water by suction, by pressing with rolls and by drying with steam fans dryers. The pulp is dried to a solid content of 90 per cent. The drying process uses large amount of heat. This however depends on how efficient the draining of the pulp is and the efficiency of the heat recovery equipment (EPIS 1999).

Chemical and energy recovery system
The cooking chemicals are recovered for economic and environmental reasons (EPIS 1999).

The recovery system in a kraft pulp mill has three functions:

- the recovery of the inorganic pulping chemicals
- the destruction of the dissolved organic material and recovery of the energy content as process steam and electrical power
- the recovery of valuable organic by-products (e.g. tall oil)

The main process units in the chemical recovery system are the evaporation of the black liquor, combustion and casticizing, including lime regeneration. The used cooking liquor (black liquor) washed out from the pulp is thickened by evaporation and used as fuel.

6.3. Material flow characteristics

6.3.1. Input

Raw materials

In the kraft pulp process all wood species can be used as raw material. Logging and sawmill residues can also be pulped and the wood does not have to be as clean as in other pulping processes (The Finnish Ministry of the Environment). Spruce, pine and other conifers are used as raw material in Norway. A factor of 4.1 m^3/tonne product is obtained by using data from the Industry Statistics. This is about the same as the Swedish values, which lie between 4.0-5.1 m^3/tP, dependent on the product, if it is bleached soft- or hardwood or unbleached softwood. No such split as this can be done in our work due to confidentiality reasons. A factor for the use of pulp, paper and board waste cannot be derived also due to confidentiality rules.

The chemicals used in the different stages of the process are described in section 6.2. The chemical volumes used to derive factors in this work are estimated based on data from 1993, and give a factor of about 227 kg/tP (oxygen excluded). This agrees with the Swedish value of 200 kg process materials/tP (EPIS 1999).

Energy

Most of the consumed energy is used for heating fluids and for evaporating water. The heat is also used for accelerating or controlling chemical reactions.

Energy data are available from the Energy Statistics in Statistics Norway for each plant. Consumption of wood, wood waste and black liquor is however only available from the Institute of Energy Technology, IFE (1999a). These data are also used in the energy accounts and in the emission inventory made by Statistics Norway, as these energy commodities not are included in the survey by the Industry Statistics. The energy consumption per tonne product produced is shown in table 6.1. In addition there is reported use of ’other’, which can not be included due to confidentiality reasons. It is not specified what is included in ’other’, but according to IFE biofuels, waste paper, sludge etc. may be included in this group. Swedish factors are shown in the table for comparison.

Table 6.1. Energy use per tonne product. 1997. GJ/tP

Energy type	Norway	Sweden[1]
Total	23.1	21.7
Wood, residues and black liquor	11.8	18.8
Fuel oil	6.1	1.8
Electricity	5.2	1.1

[1] Process heat not included.

Source: Energy Statistics, Statistics Norway, Institute for Energy Technology (1999a) and EPIS (1999)

The total use of energy is at the same level in Norway and Sweden. The factors indicate that there are more use of fuel oils and electricity in Norway compared to Sweden. The mixture of energy used may however vary from year to year due to changing prices.

Water
No Norwegian data are available. A Swedish factor of > 94 m^3 process water/tP is given in the Swedish EPIS work. This factor is used due to lack of Norwegian data.

6.3.2. Output

Main product
Pulp produced for sale and paper produced, are to be regarded as the main products. The total production of pulp for sale and paper are 705 ktonnes (PRODCOM 21.11.11/12/13 and PRODCOM 21.12) in 1997 according to the Industry Statistics.

By-product
PRODCOM 24.14 tall oil is considered as a by-product in the balance.

Waste water
Waste water from the production contains several compounds emitted in the process. Both organic and inorganic compounds are emitted, originating from dissolved wood and residues of chemicals used in the process. The wastewater also contains suspended solids such as fibre, bark particles and insoluble inorganic material. Data are available from INKOSYS, but due to confidentiality reasons only COD, suspended organic matter, and nitrogen and phosphorous given together can be used.

A factor of 94 m^3 effluent/tP (bleached) is given in the Swedish EPIS work. This factor is used in the balance due to lack of Norwegian data. A factor of 30 m^3 effluent/tP (unbleached) is also given in the Swedish EPIS work, but only one factor is used in this work as there cannot be made one balance for each type of pulp due to confidentiality reasons.

Waste
The production of kraft pulp generates waste such as sludge, ashes, rejects, dregs and lime mud. Sludge generated in waste water treatment (primary and biosludge, bark sludge etc.) is normally burnt with a mixture of bark and wood residues (The Finnish Ministry of the Environment 1997). Amounts of waste from mechanical and chemical pulping given together are the only data available. See the discussion under mechanical pulp. In the Swedish EPIS work a factor of 100 kg/tP total waste (to landfill) is given. This factor gives an amount of about 70 ktonnes waste when using the Norwegian production data. Since Norwegian data on waste at such detailed level of NACE as needed in this work is lacking, the Swedish factor is used.

Air emissions
The most important air emissions are particulate matter, sulphur dioxide, hydrogen sulphide (H_2S) and nitrogen oxides (NO_X). Emission data are available from the Norwegian emission inventory. Emissions of SO_2 are however available from the Norwegian Pollution Control Authority (INKOSYS) as mentioned in section 3.2. The same figures for SO_2 are also used in the Norwegian emission inventory. Emissions of the different components given by the sources of the emissions, whether they originate from processes or combustion, can not be used due confidentiality reasons. Emissions of H_2S are available from INKOSYS, but can not be used due to confidentiality rules. Table 6.2 shows the emissions per tonne product.

Table 6.2. Emissions per tonne of product. 1997. kg/tP

	SO_2	NO_x	CO_2	CH_4	N_2O	NMVOC	Particulate
Chemical pulp and paper	1.18	1.49	479	0.22	0.06	0.05	0.15

Source: Emission inventory, Statistics Norway and Norwegian Pollution Control Authority.

Corresponding factors for Sweden are 1.4 kg SO_2/tP and 1.4 kg NO_x/tP (EPIS 1999). The factor for SO_2 is higher than the Norwegian coefficient, but the factors for NO_x for the two countries are very similar.

One reason for the differences between the Swedish and the Norwegian factors may be due to use of different energy commodities and different degree of abatement. Another reason may be that the production processes may differ from one plant to another within the same country, so it is likely that it differs even more from one country to another. The wood-processing industry is not a homogenous industry.

6.4. Overview results

Table 6.3 shows an overview of the material flow characteristics for production of chemical pulp. The difference between input and output is about 1590 kg/tP (pulp produced for sale and paper). The differences may mainly be due to underestimation of waste generated and uncertainty concerning the water flow. A Swedish factor for waste generated has been used, due to lack of Norwegian data at such detailed level. The factor applies for waste to landfill only. It is also important to note that water is only partly included in the balance due to lack of data. Since the wood-processing industry has a high water demand this will be a serious lack in the balance. Another explanation to the difference observed is the fact that several data cannot be used due to confidentiality reasons.

Table 6.3. Material flow characteristics for chemical pulp production

INPUT	Unit	Value	Value, kg/tP
Energy carriers			
- Wood, residues and black liquor	GJ/tP	11.8	834
- Fuel oils[1]	GJ/tP	6.1	150
- Other	GJ/tP	:	
- Process heat	GJ/tP	..	
- Electric power	GJ/tP	5.2	
Raw materials and operating substances			
Raw materials	m^3/tP	4.1	2043
Operating substances	kg/tP		227
Oxygen	m^3/tP	:	
Water			
Process water [2]	m^3/tP	> 94	> 94000
Cooling water	kg/tP		..
OUTPUT			
Product	tP	1	1000
By-product			
24.14	kg/tP		16
Waste water			
Process water [2]	m^3/tP	94 (bleached)	94000
Cooling water	kg/tP		..
COD	kg/tP		63.4
BOD	kg/tP		..
tot-N+tot P	kg/tP		0.02
Suspended organic matter	kg/tP		4.0
Waste			
- Total waste [2]	kg/tP		100
- Production waste	kg/tP		..
- Hazardous waste	kg/tP		..
- Sludge	kg/tP		..
- Waste from energy production	kg/tP		..
Air emissions	kg/tP		
- SO_2	kg/tP		1.2
- NO_x	kg/tP		1.5
- CO_2	kg/tP		479
- CH_4	kg/tP		0.2
- N_2O	kg/tP		0.06
- CO	kg/tP		0.03
- NMVOC	kg/tP		0.05
- Pb	kg/tP		0.0001
- Cd	kg/tP		0.000004
- Dust	kg/tP		0.15
- H_2S			:
Difference input-output			*1588*

Data not available ..
Not for publication :
[1] Include heating oil, heavy distillate and heavy oil.
[2] Factor from the Swedish EPIS-work (EPIS 1999).

7. Results for manufacture of paper and paperboard

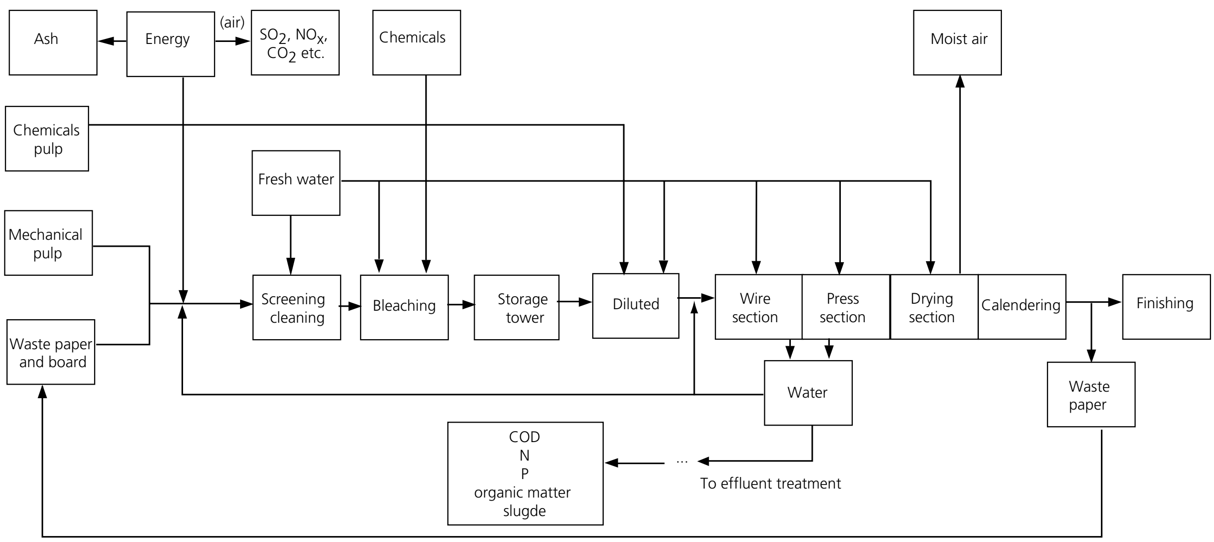
7.1. Process description

Nearly all types of production processes for paper and paperboard have the following basic units:

- stock preparation
- a paper or board machine consisting of
  - -a wire section
  - -a press section
  - -a drying section
  - -a reeler

In the stock preparation step the pulp might be refined and cleaned for the removal of impurities. Before entering the paper machine the fibre suspension is diluted. In the wire section of the paper machine the pulp is de-watered by filtration. In the press part the pulp is further de-watered before the drying section were the paper web is dried so the water content becomes only 5-10 per cent (The Finnish Ministry of the Environment 1997).

Figure 7.1 Material flow characteristics for paper production



7.2. Material flow characteristics

7.2.1 Input

Raw materials

Newsprint

Traditionally newsprint has been made of 70-85 per cent groundwood pulp and 15-30 per cent chemical pulp. The last decade it has been possible to produce newsprint without chemical pulp. One disadvantage with mechanical pulp is that the paper made of it turns yellow when it is left in daylight. As the lifetime of newsprint is short, this is a minor problem.

Hyrdosulphite bleaching is sometimes used for newsprint. Peroxide bleaching can also be used (The Finnish Ministry of the Environment 1997).

Magazine paper
About half of the pulp in magazine paper is mechanical pulp. Some grades contain 15-35 per cent filler clay while the rest is chemical pulp. The mechanical pulp is, in most cases, bleached with peroxide (The Finnish Ministry of the Environment 1997).

Wood-free printing and writing paper
Paper used for documents with long lifetime has to retain its colour. This kind of paper (wood-free paper or fine paper) is made from bleached chemical pulp with the addition of a filler.

Board
The raw materials for board production are both mechanical and chemical pulp, with the mechanical pulp in the middle, to achieve the desired stiffness.

Paper and paperboard are to be regarded as the main products. When using estimated data, based on raw material data from 1993, factors of 565 kg pulp/tonne product and 693 kg waste paper/tonne product are derived.

Energy
About 90 per cent of the heat energy are used for drying of the paper (The Finnish Ministry of the Environment 1997). The rest is used for heating the process and the building. Energy data is available from the Energy Statistics in Statistics Norway. Consumption of biofules is available from the Institute for Energy Technology (IFE), as this is not included in the survey by Industry Statistics. No data on use of biofuels in the manufacture of paper and board is however available from IFE for 1997, as no data were reported. Table 7.1 shows energy use per tonne paper produced. The factors from the Swedish EPIS work are given for comparison.

Table 7.1. Energy use per tonne product. 1997. GJ/tP

Energy type	Norway	Sweden
Total	14.9	8.9
Fuel oil	6.8	2.7
Electricity	6.4	1
Biofuels and residues	..	0.2
Process heat	..	5
Other[1]	1.7	

Data not available ..
[1] Other fuels, not specified.
Source: Energy Statistics, Statistics Norway, Institute for Energy Technology (1999a) and EPIS (1999).

As seen in the table, the factors for total use of energy is higher in Norway than in Sweden. This may be due to different conditions at the plants.

Water
There are no Norwegian data available on water used. A factor of > 45 m^3 effluent/tP is given in the Swedish EPIS work. This factor is used in the balance due to lack of other data.

7.2.2 Output

Main product
In 1997 it was produced 220 ktonnes paper and paperboard (PRODCOM 21.12) in paper mills in Norway according to the Industrial statistics.

Waste water
The wastewater from mills manufacturing paper and paperboard contains several substances including suspended solids and dissolved organic matter. The amounts of suspended solids discharged depend on the measures taken at the mills and on the accuracy of operation. The main sources are cleaner rejects, occasional spills and white water. Data on discharges of different components to water are available from INKOSYS. Due to confidentiality rules, discharges of different metals have to be given as a sum, and AOX (absorbable chloroorganic compounds) and quantities of water can not be included in the balance due to confidentiality.

A factor of 45 m^3 effluent/tP is given in the Swedish EPIS work (EPIS 1999). This factor is used due to lack of Norwegian data.

Waste
The production generates solid waste such as bark, sand and fibres from cleaning of the pulp before pumping into the paper machine. Other waste types generated are sludge, ash, metal, plastics, glass, chemicals, coating residues etc.

As mentioned earlier, data for waste generated in pulp, paper and publishing sector are available. A further distribution of these data into the three categories will be very uncertain, but a rough estimate is given in table 5.3. But using this estimate gives a factor of over 350 kg waste/tonne product produced, which is very high compared to the Swedish factor of about 50 kg/tP. Obviously, some of the paper and board waste assumed generated from paper production is generated from integrated mills. The Swedish factor is used in lack of Norwegian data.

Air emissions
Emissions to air include SO_2, NO_X, VOC, and N_2O, and data are available from the Norwegian emission inventory. The emissions originate from the energy production at the mills.

7.3. Overview results

Table 7.2 gives an overview of the coefficients for production of paper. There is a difference of -110 kg/tP between input and output. This may be due to uncertainty connected to the water flow, waste generated and use of raw material. The input of water is assumed to be like the output of water in lack of other data. Since manufacture of paper has a high water demand, this will be a serious lack in the balance. A Swedish factor is used for the total waste generated in lack of Norwegian data. In the Swedish EPIS work it is emphasised that this factor is a very rough average. The raw material data used are estimated based on data from 1993.

Table 7.2. Material flow characteristics for paper production.

INPUT	Unit	Value	Value, kg/tP
Energy carriers			
- Fuel oils[1]	GJ/tP	6.8	164
- Other	GJ/tP	1.7	
- Process heat	GJ/tP		
- Electric power	GJ/tP	6.4	
Raw materials and operating substances			
Mechanical and chemical pulp	kg/tP		565
Waste paper and board	kg/tP		693
Operating substances	kg/tP		67
Water			
Process water[2]	m^3/tP	> 45	> 45000
Cooling water	kg/tP		..
OUTPUT			..
Product	tP	1	1000
Wastewater			
Process water[2]	m^3/tP	45	45000
Cooling water	kg/tP		..
COD	kg/tP		12
BOD	kg/tP		..
tot-N	kg/tP		0.1
tot-P	kg/tP		0.01
Suspended matter	kg/tP		1.7
Suspended organic matter	kg/tP		3.6
Metals	kg/tP		6.2
Waste (total)[2]	kg/tP		50
- Production waste	kg/tP		..
- Hazardous waste	kg/tP		..
- Sludge	kg/tP		..
- Waste from energy production	kg/tP		..
Air emissions			
- SO_2	kg/tP		1.3
- NO_x	kg/tP		0.7
- CO_2	kg/tP		523
- CH_4	kg/tP		0.02
- N_2O	kg/tP		0.005
- NMVOC	kg/tP		0.06
- Pb	kg/tP		0.0001
- Cd	kg/tP		0.000002
- Dust	kg/tP		0.1
Difference input-output			*-110*

Data not available ..
[1] Include heating oil, heavy distillate and heavy oil.
[2] Factor from the Swedish EPIS work (EPIS 1999).

8. Conclusion

It is not easy to make a material balance for the wood-processing industry, as this is not a homogenous industry. Several plants seldom make the exact same product with the same kind of production equipment. The conditions often vary from one plant to another. A disadvantage in this work is that data on raw material used in 1993 are the only available at present, while almost all the other data used in the balance applies for 1997. The use of raw material in 1997 has been estimated based on the data from 1993. The data availability for waste and wastewater at such detailed level of NACE needed are scarce. This will be a serious lack as these components contribute considerably to the balance.

Although the coefficients found may have a certain uncertainty, compared to Swedish factors the Norwegian factors seem reliable. It is important to remember that the conditions may vary from one plant to another and the factors apply for a process in general and not for one particular plant. The coefficients should be seen as a first attempt to produce different factors for different processes.

A large plant, which will recycle paper from collected paper, magazines, newspaper etc., is planned to start up in Norway in the spring 2000. According to the annual report from the main wood-processing company in Norway, the fraction of waste that is used for energy purposes is increasing, and at the same time the fraction of waste for deposition is being reduced. These examples of coming changes reflect that the coefficients for the wood-processing industry may change more compared to other branches in the near future. It is important to consider this when using the factors.

While working with this project, Statistics Norway had contact with the Norwegian Product Register concerning our work with chemicals in EPIS. It was discovered that data on use of chemicals for the wood-processing industry could not be found for a detailed NACE level in the register. This is due to the fact that most of the importer/manufacturers have not reported a detailed NACE of where the chemicals are used to the register. For use in EPIS, the quantities of chemicals should preferably be given at the most detailed level of NACE to get as reliable coefficients as possible.

Further proposed work in the EPIS field is to set up EPIS for the household sector and to extend the work on chemicals in EPIS. How data can be aggregated to indicators will be an issue included in the latter project. Another future proposal for work is to test the relevance of EPIS data developed in other pilot countries to some sectors in Norway.

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