

Forest industry as a producer and consumer of wood-based energy in Finland

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This article summarizes the importance of the forest industry in the acquisition and consumption of wood-based energy in Finland. Opportunities to increase the efficiency of energy utilization further are discussed, as well.

The forest industry uses 25 % of the total energy and 40 % of the total electricity. It also generates considerable amounts of heat and electric power as byproducts of wood-processing. Wood in a form or another accounts for 64 % of the fuels of the forest industry. Consequently, the need for outside, imported energy is minute. Black liquor of pulping is dominant as a source of wood-based energy. In addition, plenty of wood residues (bark, saw dust, planer shavings, grinder dust, screening reject of chips) and minor amounts of for wood processing unsuitable fractions obtained in conjunction with harvesting small-sized whole-trees, tree sections and logging residues are used for energy production.

Tässä raportissa esitetään yhteenveto metsäteollisuuden merkityksestä puupohjaisen energian tuottajana ja kuluttajana Suomessa. Lisäksi esitellään mahdollisuuksia energian käytön tehokkuuden edelleen parantamiseksi.

Metsäteollisuus käyttää kaikkiaan 25 % kaikesta Suomessa kulutettavasta energiasta, ja 40 % kaikesta sähköstä. Se myös tuottaa huomattavia määriä lämpöenergiaa ja sähkövoimaa puunjalostusprosessien sivutuotteena. Puu muodossa tai toisessa kattaa 64 % metsäteollisuuden polttoainetarpeesta. Sen ansiosta erityisesti tuontienergian tarve on vähäinen. Selluteollisuuden jätelipeä on selvästi tärkein puupohjaisen energian lähteistä. Lisäksi energian tuotantoon käytetään runsaasti puujätteitä (kuori, sahanpuru, höylänlastu, hiontapöly, hakkeen seulontajäte) sekä vähäisiä määriä kokopuu-, osapuu- ja hakkuutähteiden korjuussa kertyviä, metsäteollisuustuotteiden raaka-aineeksi kelvottomia jakeita.

Keywords: forest products industries, fuels, fuelwood, wood residues, black liquor, calorific value.

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Introduction

The forest industry is the biggest consumer of energy in the Finnish national economy. Its proportion is about 25 % of the total consumption of primary energy and upto 40 % of the consumption of electric power (Laine 1992). The forest industry uses the share of as high as 60 % of the industrial use of energy. The proportion of energy of the total manufacture cost, and the total energy consumption vary a lot between different wood products (Table 1). The proportion is the lowest in lumber and plywood and the highest in chemical pulps and certain paper grades. The total energy consumption is the lowest in the manufacture of lumber, particle board and mechanical pulps and the highest in the manufacture of bleached sulphate pulp, kraft paper and tissues.

To counterbalance the ample energy consumption, the forest industry also generates considerable amounts of heat and electric power as by-products of wood processing. That is why the need of energy from elsewhere is inconsiderable. Moreover, the figures in Table 1 on the level of energy consumption in the forest industry can be considered fallacious as regards the true energy cost.

The progress of the energy supplies and the proportion of the domestic energy in the Finnish forest industry from the early 1970's is shown in Fig. 1. Over 15 years the proportion of oil has diminished from 37 to 5 %. The change is mostly due to the increased use of nuclear and natural gas energy. In addition, the use of domestic fuels, mainly wood and peat has increased from 45 to 57 %.

The total use of fuels was 189 PJ in the forest industry during the one-year period from July 1990 to June 1991, and the degree of fuel domesticity was as high as 70 % – as it was only 30 % in the whole country (The wood-based fuels... 1990, Laine 1992). Domestic fuels were used of 135 PJ which was made up of 122 PJ wood-based fuels and 18 PJ peat. In the future the use of wood-based fuels, peat and natural gas is planned to be slightly increased, whereas the use of oil and coal will remain at the present level.

In 1989 the consumption of electric power was about 68.4 PJ in the forest industry, and it will possibly be increased due to the planned expansion in pulp and paper (A key to the Finnish... 1990). In addition to the generation of counterpressure power in processing, the forest industries generate electric power at their own

Table 1. Role of energy cost and total energy consumption in the manufacture of different forest products in Finland. The data refers to Iivonen 1986, Laine 1992, Simola 1985 and Usenius 1982.

Forest product	Proportion of energy of the manufacture cost, %	Heat	Electricity GJ/m ³ or ton	Total
Softwood lumber	9–10	1.5	0.2	1.7
Basic birch plywood	8–10	8.2	1.1	9.3
Particle board	10–15	4.3	0.7	5.0
Fibre board	35	9.3	2.3	11.6
Groundwood pulp from Norway spruce	20	-	5.2	5.2
Thermomechanical pulp from Norway spruce	30	-2.1	7.6	5.5
NSSC pulp from birch	40	7.2	1.9	9.1
Unbleached sulphate pulp from Scots pine	40	15.2	1.8	17.0
Bleached sulphate pulp from Scots pine	50	21.2	2.7	23.9
Newsprint	45	7.5	2.5	10.0
Coated woodcontaining paper grades	35	9.2	2.2	11.4
Coated woodfree paper grades	35	9.4	2.9	12.3
Kraftpaper	40	10.8	3.6	14.4
Kraftliner, fluting	30	7.1	1.6	8.7
Tissues	35	10.2	4.1	14.3

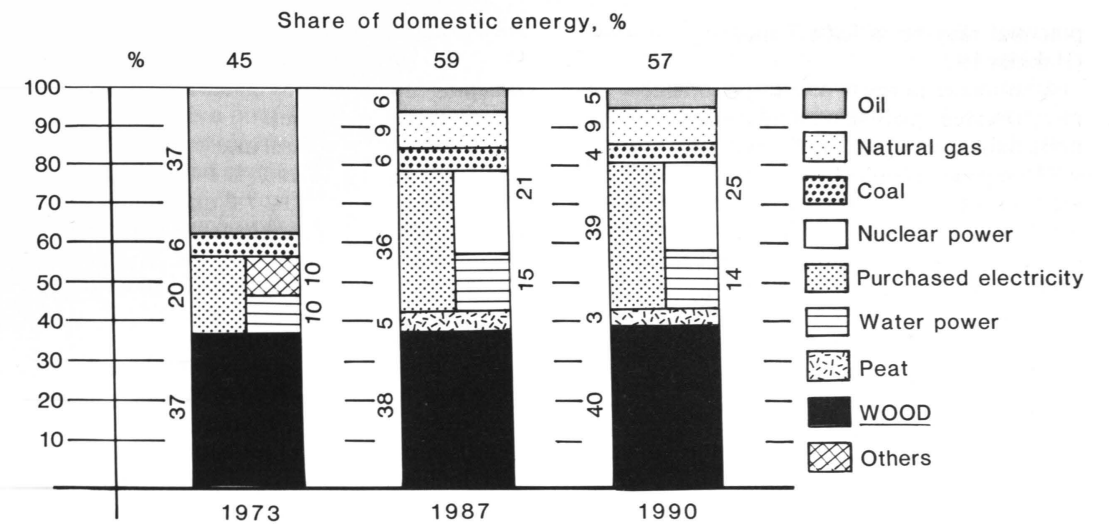


Fig. 1. The progress of the energy sources in the Finnish forest industry, and the share of domestic energy. The data refers to A key to the Finnish... (1990) and Laine (1992).

condensation and water power plants. Thus, they generate a total of 35 % of the Finnish power production and more than 90 % of their own electric use.

Though the forest industry uses a large share of energy in Finland, the use of energy per product unit has decreased considerably over the years: the energy demanded to manufacture one product unit decreased by 36 % from the early 1970's (Laine 1992). This shows that great efforts have been made in the field of saving energy, as well.

This article aims to summarize the importance of the forest industry in the consumption and acquisition of wood-based energy in Finland. Opportunities to increase the efficiency of energy utilization are discussed, as well.

Role and sources of wood-based energy

When considering the scope of energy use of wood in the forest industry, it is aimed to find an optimum between the use in wood processing and energy production. The criteria are related to both the business and national economies. Nowadays the proportion of wood-based energy is approaching the level of 40 % in the Finnish forest industries (A key to the Finnish... 1990, Laine 1992).

The role of black liquor in chemical pulping is dominant as a source of wood-based energy.

Its proportion of the total Finnish energy consumption was as high as 7 % in 1990 (Laine 1992). At a modern pulp mill more than 85 % of the wood-based heat generation is yielded from black liquor. Actually, the energy generation exceeds the pulp mill's own needs, and it is possible to deliver extra energy to an integrated paper mill. The importance of the energy generated by pulp mills will possibly increase with pulping capacity during the late 1990s.

Both the mechanical and chemical wood processing can utilize the energy from wood handling residues such as bark, sawdust, planer shavings, sander dust, unmerchantable chips and screening reject of pulp chips. In 1973 for example, 50 % of bark was used for energy and 7 % for other commercial purposes, such as soil-improving agents (Timber report 1976). At present the estimated proportion of bark for energy is more than 90 % (Laine 1992). – It is remarkable that, contrary to many other forest industry countries, wood handling waste was used in large amounts already before the energy crises of 1973–74 and 1978–79.

The surplus of technically merchantable timber from the Finnish forests has recently resulted in a severe problem of first thinnings, because timber from the first thinnings has high logging cost and low timber quality compared with timber from final cuttings. That is why, the use of the timber from first thinnings for energy would currently be well-justified. Their annual

potential may be at least 7 mill. m³, or 45 PJ (Hakkila 1992).

Additional energy wood (tops, branches, unmerchantable small-sized stems) is not procured more than approx. 0.05 to 0.1 mill. m³, or 0.4 to 0.8 PJ a year. It is procured in conjunction with the harvesting of pulpwood as tree sections and whole-tree chips. The amount is minute compared with the total annually harvestable biomass of small-sized trees for energy, 9.8 mill. m³, or 64.3 PJ (Hakkila 1982, 1992). Other potential sources of energy wood, such as logging slash, stumps and roots, and few experimental short-rotation plantations of hardwoods are not utilized nowadays by the industries, despite their large annual potential of 5.4 mill. m³, or 52 PJ (Hakkila 1982, 1992). The full utilization of the energy potential of the tree biomass for the forest industries would increase their use of wood-based energy almost threefold.

Wood-based energy in the mechanical forest industry

Wood residues of sawmills

When sawing Nordic softwood logs, the yield of the main product, lumber, is relatively low. In general, lumber can be yielded 42 to 46 % from the log volume over bark (Pelkonen 1986). Individual effective sawmills are able to reach a recovery of 52 % and the trend is for better utilization of the logs. All the rest of the log volume goes for byproducts: chips (27 to 32 %), saw dust (10 to 15 %), bark (12 %) and shrinkage in drying, oversize etc. (4 to 6 %) (Pelkonen 1986).

The amount of chips depends on log size – the minimum diameter is typically 15 cm for Scots pine and 16 cm for Norway spruce – and log quality, log sorting practices and the optimization degree of sawing, edging, drying and trimming of lumber. The more square-edged lumber is aimed for, the thinner the saw blades and the more chipper canters are used, the bigger the chip proportion is. The dependence of the sawdust amount on these factors is reverse. In addition, the sawing patterns to maximize the board yield increase the amount of sawdust.

Chips from sawmills and plywood mills hold a share of 25 % in the wood raw material basis of sulphate pulp mills in Finland (Klemetti 1987). To meet the requirements of the pulp mills, chips must be screened at the sawmill. The re-

ject is either used for energy or sold along with the sawdust for pulping. The proportion of screening reject depends on the chip quality and the screening technique.

In 1983, when 8.0 mill. m³ merchantable lumber was produced – which is 1–2 mill. m³ more than now (Aarne 1992) – 7.5 mill. m³ chips and sawdust and 2.0 mill. m³ bark were accumulated. Seventy-five percent of chips were sold for pulping and 10 % for chip- and fibreboard mills, and 15 % was used for the sawmills' own energy production (Arpiainen et al. 1986). The corresponding proportions of the sawdust were 40, 17 and 47 %. Roughly 70 to 80 % of bark was used for energy.

The energy production from sawdust has maintained its important role, and that from bark has continuously increased. Some amounts of sawdust and bark are even delivered to municipal heating plants, although this use is constrained by the lack of suitable customers, and the long transport distances. The investment contribution programme by the state to heating plants using domestic energy, which was established after the energy crises, has somewhat increased their number.

The heat values of the different sawmill residues at their normal moisture content are as follows (Usenius 1982):

Type of residue	Normal MC, %	Heat value, GJ/green ton
Bark, Scots pine	60	6.6
Bark, Norway spruce	60	6.0
Chips, Scots pine	50	8.4
Chips, Norway spruce	50	8.3
Sawdust, Scots pine	50	8.6
Sawdust, Norway spruce	50	8.5
Planer shavings	10	16.8

Bark is normally handled with a bark press before burning to decrease the moisture content. Pressing the bark from water-stored logs, which has a moisture content of up to 80 %, is often necessary to guarantee an appropriate burning. Most bark burning plants require a minimum dry matter content of 40 %. Especially the bark of spruce, which tends to be removed in strips, is often crushed to make the particles more homogeneous and, thus, to improve the ability for handling, drying and feeding to a fire grate.

The heat value of sawdust depends a lot on the log storing method and the process of where it comes from. The heat value of sawdust from water-stored logs is low, which is why dry plan-

er shavings are often mixed in. The sawdust from trimming is drier than that from sawing. In addition, it is extremely fine by grain size and, as a result, it has a poor suitability for pulping. Thus, it is reasonable to use it for energy.

Thanks to wood residues, the self-sufficiency degree of heating energy is high at Finnish sawmills: in 1982 wood residues worth 4.3 PJ accounted for 78 % of the total use of 5.5 PJ heat energy, and the self-sufficiency degree was as high as 93 % (Arpiainen et al. 1986). The smallest sawmills excluded, bark is the most economic fuel, which can be seen in the bark proportion of 53 % and the sawdust proportion of 25 % of all heating fuels.

The main part of the heat energy, 85 to 100 %, was used for lumber drying. The newly-built sawmill halls in particular have heating systems which take an average proportion of 10 % of the heat consumption. Some sawmills use primary energy for heating the log pond. Process waste heat is the most available at the integrated sawmills.

The consumption of electric power at the sawmills, which was 1.6 PJ in 1982 (Arpiainen et al. 1982), depends on the degree of mechanization of the process and on the proportion of lumber to be dried. The self-sufficiency degree of electric power was 34 %, including that from the sawmills' own production and that from the power plants of the forest industry integrates. A typical distribution of the consumption of electric power to the different process phases is as follows (Iivonen 1986):

Process phase	%
Artificial drying	39
Sawing	28
Log handling and debarking	10
Trimming, sorting and planing	8
Others	15
Total	100

Wood residues of plywood mills

The yield of the final product is abnormally low at Finnish plywood mills, only 27 to 32 % (Heikkilä 1985), compared with those in Central Europe and North America, for example. Small log diameters partially explain the situation: the minimum diameter is 18 cm for European birch and 20 cm for softwoods. Despite the progress in plywood manufacture techniques and the in-

crease in automation, the recovery has not improved markedly. This is due to the decrease in the dimensions and the quality of birch logs, which is the main raw material. Recently the progress has turned to a better direction thanks to ADP-based recovery optimization, which regulates the block centering to the lathe (Tuompo 1988). Increased use of softwoods with a better recovery, mainly Norway spruce, also improves the average yield.

The raw material flows when processing birch and spruce at a Finnish plywood mill are as follows (Heikkilä 1985):

Process phase	European birch	Norway spruce
	Volume-%	
Bark	12.0	10.0
Log bucking residue	3.4	3.4
Peeling residue	5.8	6.1
Peeler cores	10.0	10.0
Dry clip residue	8.2	8.8
Edge sawing residue	19.0	19.0
Sander dust	7.0	7.0
Drying and pressing shrinkage	8.2	10.0
Ready plywood	25.7	33.0
Total	100.0	100.0

Log bucking and peeling residues and peeler cores are the most valuable byproducts, due to their suitability for pulping as chips. Their screening reject, proportion of which is 10 to 30 %, is typically used by an integrated particle or fibre board plant. Although the chips committed from dry clipping waste are heterogeneous in particle size, they are suitable for pulping when screened. Another solution is to use them for either particle or fibre board, or for energy. The urea and phenolic formaldehyde glues in the edge sawing waste make it unsuitable for sulphate pulping. A majority of the edge sawing wastes are still used for energy, along with bark and sander dust. On the whole, the proportion of energy fractions is 43 to 48 % when processing European birch, and 41 to 45 % when processing Norway spruce.

Due to the lower moisture content and the use of birch, the heat value of the wood residues from a plywood mill are higher than those from a sawmill, as follows (Usenius 1982):

Type of residue	Normal MC, %	Heat value, GJ/green ton
Bark, European birch	50	10.2
Bark, Norway spruce	60	6.0
Screening reject of chips from logbucking and peeling residues and peeler cores	40	10.5
Dry clip and edge sawing residues	10	16.8
Sander dust	10	17.6

In 1983, when 580 000 m³ plywood was produced – which approximately equals to the present production rate (Aarne 1992) – the total accumulation of wood residues was 1.3 mill. m³ (Arpiainen et al. 1986). On the basis of the above proportions of the different fractions, the amount of the energy fractions were 0.2 mill. m³ bark and 0.9 mill. m³ wood.

While bark presses are used at sawmills, they are not normally used at plywood mills, because the heat value of birch bark is high, in itself, and spruce bark is not accumulated in big quantities. However, bark is normally torn into smaller particles by bark rakes to ease handling on conveyors.

In 1982, wood residues worth 2.2 PJ accounted for 65 % of the total use of 3.4 PJ heat energy in the Finnish plywood industry (Arpiainen et al. 1986). The self-sufficiency degree was 74 %. However, burning wood residues, especially sander dust, often requires the use of a supporting fuel, such as oil or peat.

The process phase consuming the most heat at a plywood mill is veneer drying (55 to 70 %). Log steaming takes 5 to 20 %, hot pressing 3 to 15 % and heating the buildings 10 to 35 % (Simola 1985).

The total use of electric power was 0.7 PJ in the Finnish plywood industry in 1982 (Arpiainen et al. 1986). Forty to sixty percent of it was consumed by rotary cutting and drying of veneer, 15 to 25 % by log handling, steaming and chipping, as much by plywood pressing and finishing, and 5 to 10 % by veneer handling.

Wood-based energy in the chemical forest industry

Wood residues from roundwood

Wood residues accumulating in conjunction with pulping comprise bark and chip screening reject. In 1989 the Finnish chemical forest indus-

try produced 5.2 mill. tons sulphate pulp, 0.3 mill. tons sulphite pulp, 0.4 mill. tons semi-chemical pulp, and 3.2 mill. tons mechanical pulps (Aarne 1992). The production consumed 32.3 mill. m³ roundwood and 7.2 mill. m³ chips and sawdust.

When handling traditional Finnish roundwood, with a minimum diameter for pulp being 7 cm, the proportion of bark is 12 to 16 %, depending on tree species and geographic region (Saikku & Rikkonen 1986). Due to the loss during logging and transport, the bark proportions are at the mill lower than these figures show. In drum debarking, which is the dominant method at pulp mills, some wood is also released. This wood loss is 1 to 5 % for fresh and 10 to 20 % for decayed roundwood (Niiranen 1983), eventually 4 % on average. Provided that the average bark proportion of roundwood is 11 % at the mill port, Finnish pulp industries produced in 1989, 3.1 mill. m³ bark for their energy worth 2 PJ. Bark is handled before burning by the same methods as at saw and plywood mills.

The proportion of the screening reject of the chips is rather low at pulp mills, presumably 1 to 2 %. Oversize chips are often circulated to a pin chipper for rechipping, and the saw and plywood mill chips have already been screened before transport. With the above provisions, the amount of screening reject and wood lost in debarking, which are used for energy at the Finnish pulp mills, may be as big as 1 to 2 mill. m³, worth 0.8 to 1.2 PJ annually.

Wood residues from tree sections and whole-tree chips

A proven method to decrease the cost of logging small-sized trees is based on the reduction of delimiting in the forest and mass handling of trees. This trend is reflected in:

- *tree-section methods*, where the small trees are left undelimited and only bucked into suitable lengths for transport with branches.
- *forest chipping methods*, where the undelimited small trees and the tops of the large trees are chipped before long-distance transport.

The common factor in these methods is the acquisition of energy wood for industrial use simultaneously with industrial wood. Because the stands most suitable for tree-section and forest chipping methods are pulpwood-domi-

nated, the appropriate use of energy wood will be at pulp mills. The biomass harvested can, in principle, be increased by 10 to 55 % by the tree-section and forest chipping procurement (Eskelinen et al. 1984). In the most suitable conditions, which mean pine and birch stands with an average stem volume of 50 to 150 dm³, the increase is 15 to 25 %.

The actual energy wood, which is a mixture of bark, tops, branches and foliage, is separated from pulpwood in debarking drums when using tree-section procurement, or by disc and plane screens when using forest chipping procurement. Compared with a general roundwood, extra debarking, chipping, chip screening and waste conveying capacity is needed in wood handling. In tree-sections the proportion of energy fractions is 16 to 17 % units and in forest chips 2 to 10 % units higher than in roundwood for pulp (Eskelinen et al. 1984). The heat value of the energy fractions when using tree section logging approximately equals to that when using shortwood logging, but forest chip logging results to a decrease by 15 % for spruce and 40 % for birch. In total, the use of tree section procurement increases the energy from wood handling residues by two- to fourfold. The corresponding increase when using the forest chipping procurement is somewhat smaller, but the energy from black liquor is additionally increased.

The current procurement of tree sections is 0.3 to 0.4 mill. m³, and that of forest chips 0.12 mill. m³ to a total of six Finnish pulp mills (Industrial use... 1992). The tree section procurement, which produces as good-quality raw material for pulping as roundwood procurement, is moderately increasing. Instead, forest chips have mostly been neglected because of the remained chip quality problems and low-priced oil. – It must be emphasized that lack of energy does not exist at the Finnish pulp mills. Thus, the first idea in tree-section and forest chip procurement to pulp mills is not to collect extra wood residues but to reduce the real wood cost per ton of merchantable pulp.

Black liquor

In chemical pulping it is aimed to remove the other compounds than cellulose from wood with chemicals. The pulping chemicals are taken care of by the regeneration process, the extra liquid is vaporized and the rest, black liquor containing hemicelluloses, lignin and extractives of

wood, is burned for energy.

In 1989, the Finnish chemical pulping produced about 90 PJ energy from black liquor. More than half of it came from sulphate pulping. The amount of heat generated from black liquor, in the same way as that from bark, depends on the pulp yield: the higher the yield, the lower the heat generation is (Sarkomaa 1976). In typical pulping conditions of Scots pine where pulp yield is 46 to 47 %, the heat generated is approx. 15 to 16 GJ per a ton pulp. In pulping of European birch the yield is higher, which makes the heat generation lower compared with pine than the differences between the curvature levels directly show.

In mechanical pulping it is aimed to remove the fibre mass from wood with heat by grinding or refining, which results in a lower cellulose content than in chemical pulping. Thus, possibilities for a similar energy regeneration as in chemical pulping do not exist. However, a large proportion of the electric energy used for presteaming in the TMP process and for grinding/refining in all mechanical processes can be recollect as heat energy. Consequently, more heat is ostensibly produced than what is consumed by the processes.

Increasing the efficiency of the wood-based energy utilization

The demand for energy is increasing in the Finnish forest industry. Minimizing the specific energy consumption per forest product unit is thus of great importance. In an international comparison this is said to be very low in Finland. On the other hand, energy-intensive products, such as printing and writing papers based on mechanical pulps, have an unusually great emphasis in the Finnish forest industries.

The mechanical forest industry has only limited possibilities to expand the basis for wood-based energy. Bark, chips, sawdust and other wood residues that are unsuitable for pulping are already in nearly full use. The only currently economical possibilities to increase the procurement of energy-wood from forests could be chips from logging residues after logging with multi-function machines and stumps from final cutting areas. However, oil, coal and locally peat are more economical energy sources than these.

The possibilities to save energy at sawmills are linked with technical solutions in lumber drying. In a continuous kiln with a longitudinal

air-circulation it is possible to reduce the need for heating energy by 10 to 25 % by preheating the fresh air with the exhaust air, thanks to its homogenous temperature (Usenius 1982). In a compartment kiln the heat consumption varies a lot. A unit of 4 to 10 compartment kilns is needed to make it profitable to link their ventilations. Even then the heat recovery is lower and the equipment is more expensive than in a continuous kiln.

If air temperatures in parallel kilns are clearly different, it is possible to use the exhaust air from the high-temperature kiln as fresh air for the low-temperature kiln. In this way the total heat consumption can be reduced by upto 50 %. Raising the fresh air temperature in the kiln reduces the losses of ventilation. Even a rise from 40 to 50 deg. C results in a reduction of 10 to 15 % in the energy cost of a sawmill. An effective way to decrease the energy consumption is also to maximize the operation time of the sawmill. As an example, an increase in the operation degree from 70 to 90 % is estimated to produce a reduction of 15 % in the electric consumption (Usenius 1982).

At a plywood mill the demand for heat energy for veneer drying can be saved by 12 to 30 % by decreasing the volume of exhaust air, compared with unregulated drying. The increase in the degree of loading of veneer drier from 70 to 80 % decreases the energy consumption by 10 %. Sorting the veneers by moisture content before drying, for example by their heart wood and sap wood content, increases the capacity of a veneer drier by 25 to 30 %, which results in an energy saving of 20 to 25 %. An additional saving is achieved, if the incompletely dried veneers are sorted for redrying instead of continued drying of all the veneers. A press-drier, the industrial use of which has been hampered by its low capacity and the problems with resin and gas exhaust, is estimated to save 50 % of the energy needed for an ordinary web or roll drier. There often exists a need for constructional improvements in log steaming and veneer drying, too (Usenius 1982).

The role of pulp and paper is dominant in the energy consumption of the forest industry. Some increase in wood-based energy can be expected as a byproduct from the expanding use of tree section and flail-chain delimiting logging systems for whole trees. However, the expansion in sulphate pulping would increase the most the net production of wood-based energy. Improving the utilization of lost energy has proved

difficult and, most often, unprofitable at pulp and paper mills. It seems that the possibilities for saving energy are mainly linked with the choice of the equipment, such as batch cooking before continuous cooking, and with the right regulation of pumps and vents (Sarkomaa 1976).

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