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Towards Energy Self-Sufficiency in the Pulp and Paper Industry

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PREFACE

The pulp and paper industry is among the most energy intensive in basic industry branches.

Rapid price increases for purchased energy and potential risks in its availability during the 1970's have started an intensive and worldwide search for energy saving technology and other means for increasing the energy self-sufficiency in the pulp and paper industry. This paper discusses various possibilities which can and have been successfully used in different countries for the above target. Several new energy saving processes and process equipment are under various stages of development. Increased utilization of process wastes and closing of water and heat systems are other examples of the ways to improve the energy efficiency of the mills. During the 1970's the industry also found ways of saving energy by computer based process control systems. This computerization process will certainly continue and it will be extended to higher levels of hierarchy thus forming an integrated energy management and production coordination system.

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INTRODUCTION

The pulp and paper industry is one of the most energy intensive industries and so it is natural that especially after the dramatic price increase of energy based on oil and natural gas there has been a need and a clear trend to change the processes and industrial practices so that this heavy dependency on purchased energy would decrease, i.e., a trend towards energy self-sufficiency.

There are, however, big differences between different countries, different mills and different endproducts as to their dependency on external energy and energy consumption. As an example a modern bleached market kraft pulp mill can be up to 90-100% energy self-sufficient. There also exists certain paper qualities which in the near future may be fully energy self-sufficient. On the other hand the energy self-sufficiency of a modern newsprint mill is only about 20%.

The main steps towards higher self-sufficiency are; new processes and equipment, different process improvements and changes, better and closer monitoring and operation of the mills and processes i.e., extensive use of systems analytical and control engineering tools.

ENERGY CONSUMPTION IN THE PULP AND PAPER INDUSTRY TODAY

For the world's pulp and paper industry as well as for any other energy intensive industry branch, one of the most important and characterizing external disturbances during the 1970's has been the drastic and continuous increase of the price for purchased external energy. Figure 1 gives a rough schematic overlook for the price development of the crude oil.

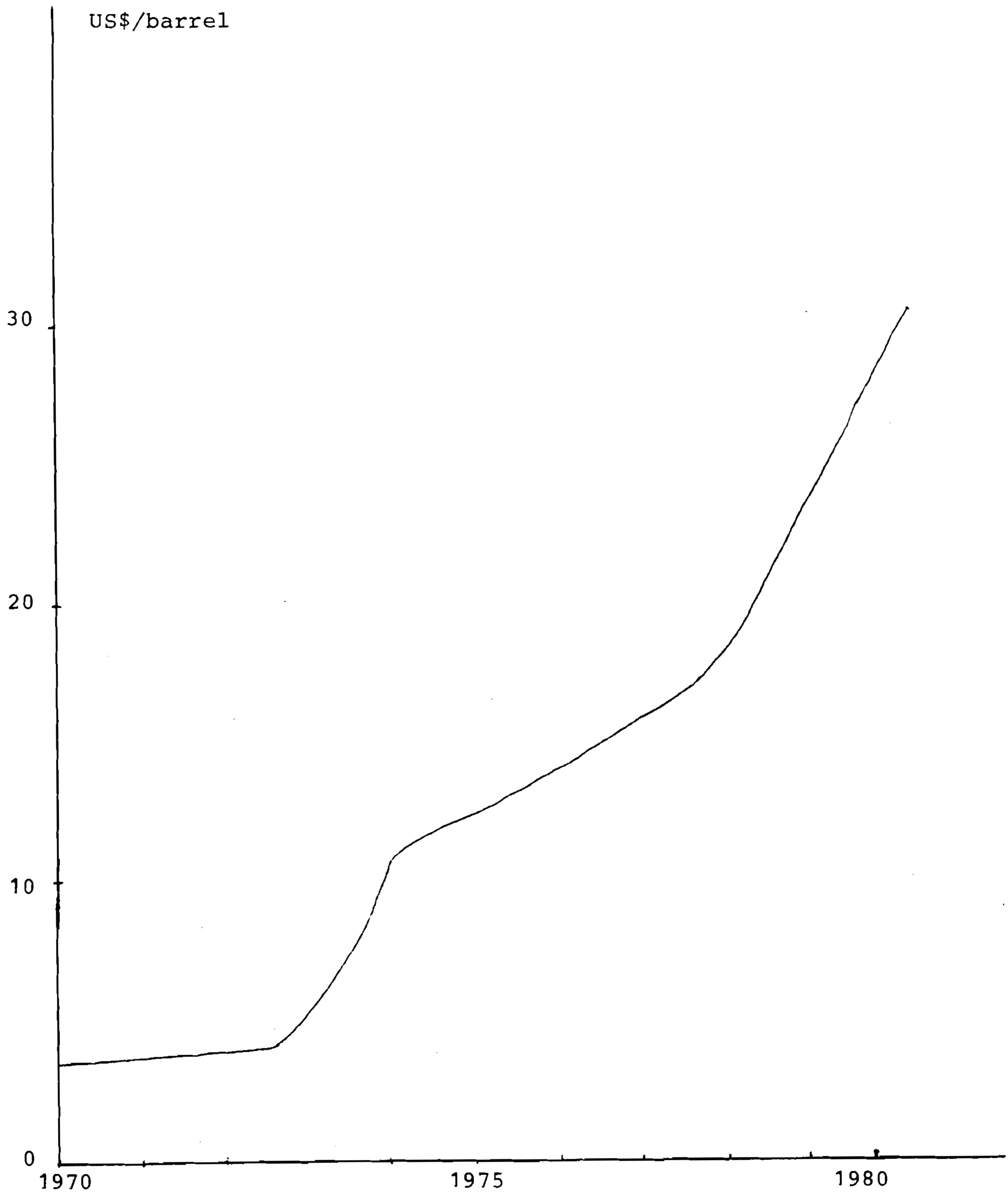

Figure 1. Price development of crude oil.

In the national context the total usage of energy in the pulp and paper industry varies a lot from country to country as can been seen from Table 1. (Norrström and Widell 1977).

The percentual share of energy costs from total production costs varies a lot depending on the endproduct of the mill. In Figure 2 I have compared the relative cost proportions of wood, steam and electricity in the production of unbleached kraft, bleached kraft, kraftliner and newsprint. The absolute values are not important and the unit prices used for wood, electricity and steam are more or less hypothetical. The most interesting here are the proportions; we can state that newsprint is much more sensitive to energy price increases than the other three products shown in the figure.

Before the so called "energy-crisis" 1973/74 the average percentual share of energy costs in nonbleached kraft market pulp mill was about 3-4% and in an integrated white paper mill 13-15% from total production costs capital costs included. Today these numbers vary from 5-20% respectively. So the effect of an increase in energy prices has not had such a dramatic change in total production costs of endproducts and thus the energy savings investments in the pulp and paper industry must compete with many other investments from the limited capital available for investments. In many countries, however, the governments have tried to favor these energy savings investments by tax reductions etc., so a lot of such projects have been completed or are going on and planned. For example, in the Finnish pulp and paper industry, the total energy savings investments 1974-1978 were about 106M$ (Kairamo 1980) and the resulted total savings 39M$/a.

As a whole the energy self-sufficiency of the pulp and paper industry for example in the US has increased from 41.5% in 1972 to 47% in 1978.(Slinn 1979). In Finland the self-sufficiency today is about 54%. This development has demanded new and advanced technology and energy and cost consciousness of the people working in this industry; so new skills and attitudes have been needed and will be needed in the future. This may become a limiting factor unless it is sufficiently notified in the education and training of managers, engineers and operators of the mills.

Table 1: Energy Consumption 1973/TWh:

	USA	Sweden	Japan	Finland
Total consumption	21000	445	3900	270
All industry	6140	160	-	90
Pulp and Paper	560	64	95	56
Pulp and Paper in % from all industry	9.1	40.0	-	62.2

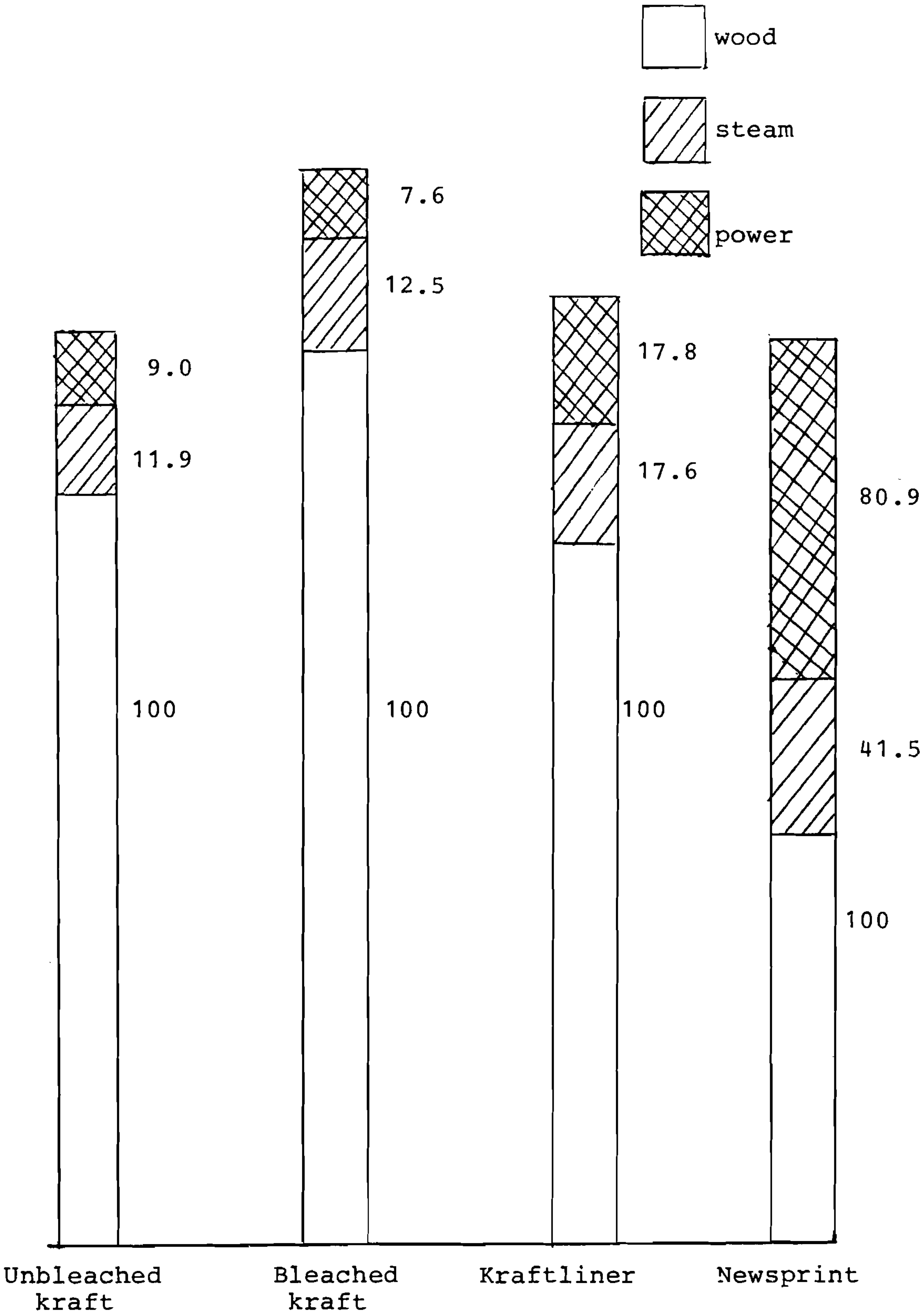

Figure 2. Relative cost proportions of wood and energy in different endproducts

In the pulp and paper industry the energy is mainly used in the form of steam, hot water and electricity; some mills also use mechanical drives and a little primary fuel is also needed in kraft pulp mills for the lime kiln. The steam is generated in recovery boilers and/or in auxiliary (power) boilers using spent liquors, bark or wood residues as fuel. Power boilers are normally multifuel boilers using oil or gas as additional purchased swing fuel. Some mills may also purchase bark and wood residues to be used as fuels in power boilers. Spent liquors in chemical pulp mills are valuable fuels and that is why a modern kraft pulp mill can today reach practically 100% self-sufficiency in energy usage. Figure 3 shows a simplified flow diagram of chemicals and energy in a kraft pulp mill and the overall energy balance of the mill is given in Figure 4. It can be stated that the amount of purchased fuel and energy in this case is rather low (ca 7% and 12% respectively); in fact it is today possible to reach a total self-sufficiency in a modern chemical pulp mill.

Table 2 gives three examples of energy balances from hypothetical mills using average existing technology. As can be seen from the table the bleached kraft pulp mill is almost self-sufficient but the others are far from that. However the existing average technology applied in pulp and paper industry today is far from the most energy efficient available and theoretically it is possible to improve the energy self-sufficiency far beyond the values of today. In Table 3 the situation in an (hypothetical) integrated linerboard mill with an annual capacity of 200.000 tons is demonstrated: we can see that the best available technology is remarkably more energy efficient than the average technology applied today and that theoretically a 100% self-sufficiency could be reached.

In Figure 5 the trend and possibilities for decreasing the per unit energy consumption in some major industries are depicted and as can be seen there exist a big potential for further improvements in the pulp and paper industry.

The question is how do we reach this target? The main areas where improvements in energy efficiency can be made are:

-- new processes and equipment
-- improvements and changes of existing processes and machines
-- better and more accurate use and operation of the processes (monitoring, control and optimization)

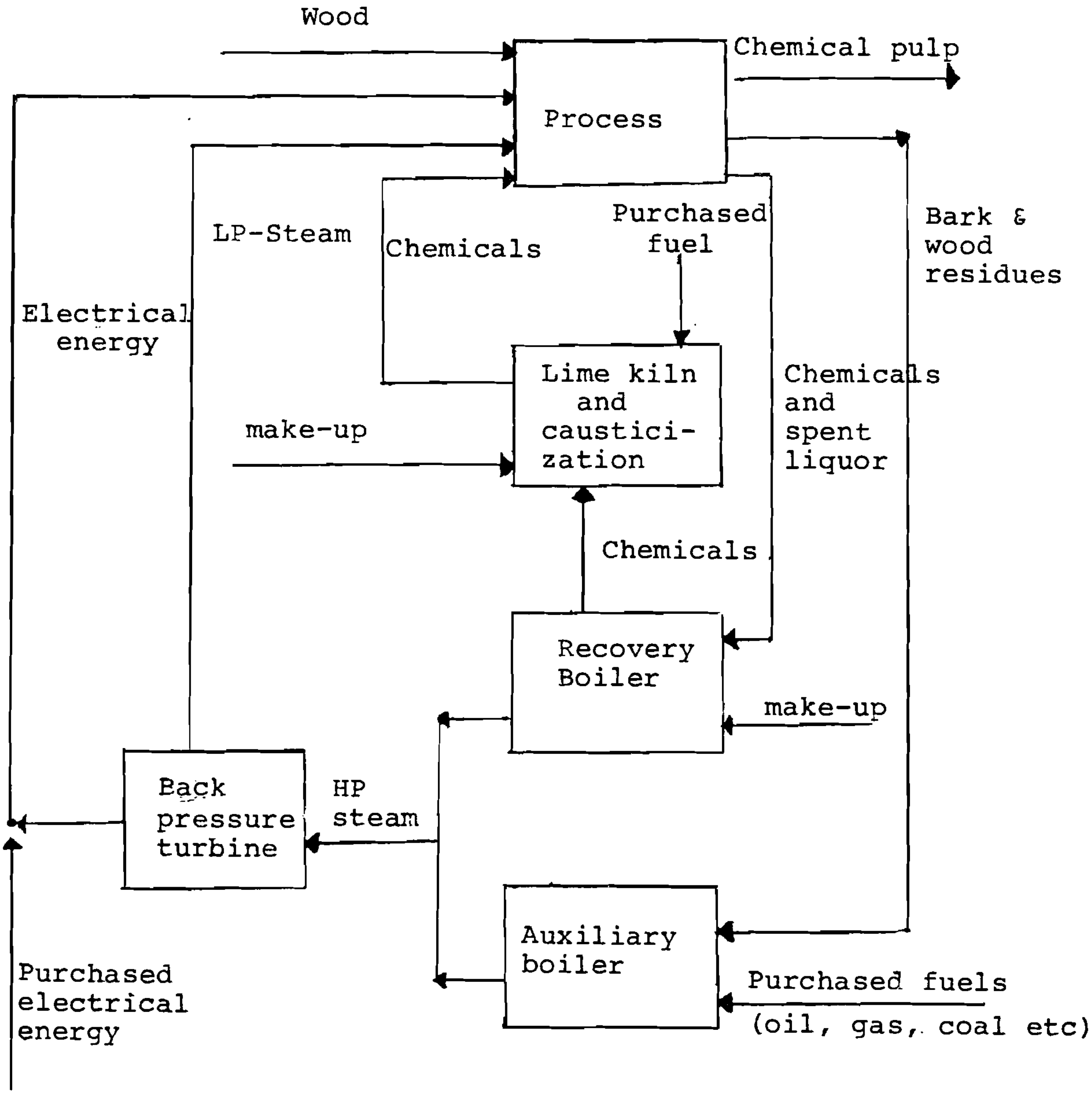

Figure 3. A simplified flow sheet of energy and chemicals in a kraft pulp mill.

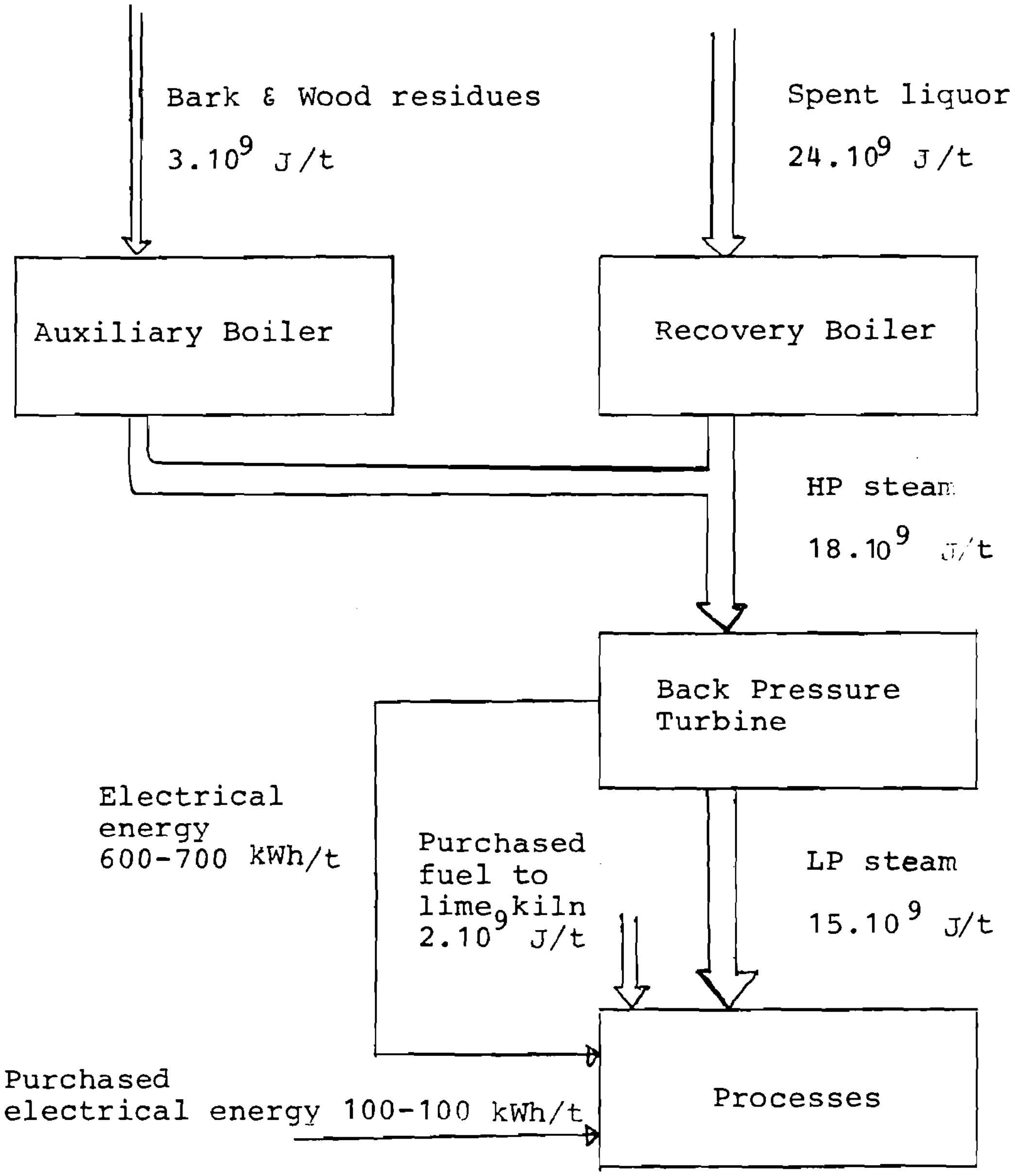

Figure 4. Overall energy balance in a kraft pulp mill.
(Per ton of air dry pulp)

Table 2. Energy balances in three hypothetical mills using average existing technology.

	Bleached kraft	Newsprint	Fluting
HEAT BALANCE MJ/t			
Consumption			
Process heat	14650	6350	10650
Primary heat	2050	-	-
Back pressure cogeneration	3250	1580	2250
TOTAL	19950	7930	12900
Generation			
Waste liquor	15800	-	3000
Bark & Wood waste	2500	900	2000
Primary energy			
-- auxiliary boiler	-400	7030	7900
-- lime kiln	2050	-	-
TOTAL	19950	7930	12900
POWER BALANCE kWh/t			
Consumption	825	1720	870
Generation			
Back pressure	850	415	600
Purchased	-25	1305	270
PURCHASED ENERGY			
Fuels MJ/t	2050	7030	8800
Power kWh/t	-25	1305	270

- indicates a surplus

Table 3. Possibilities in energy efficiency.
(Integrated linerboard mill, 200.000 tons/year)

	Heat	Electricity
Present average usage (in relative units)	1.0	1.0
Best available technology	0.33	0.5
Theoretical	0.0	0.0

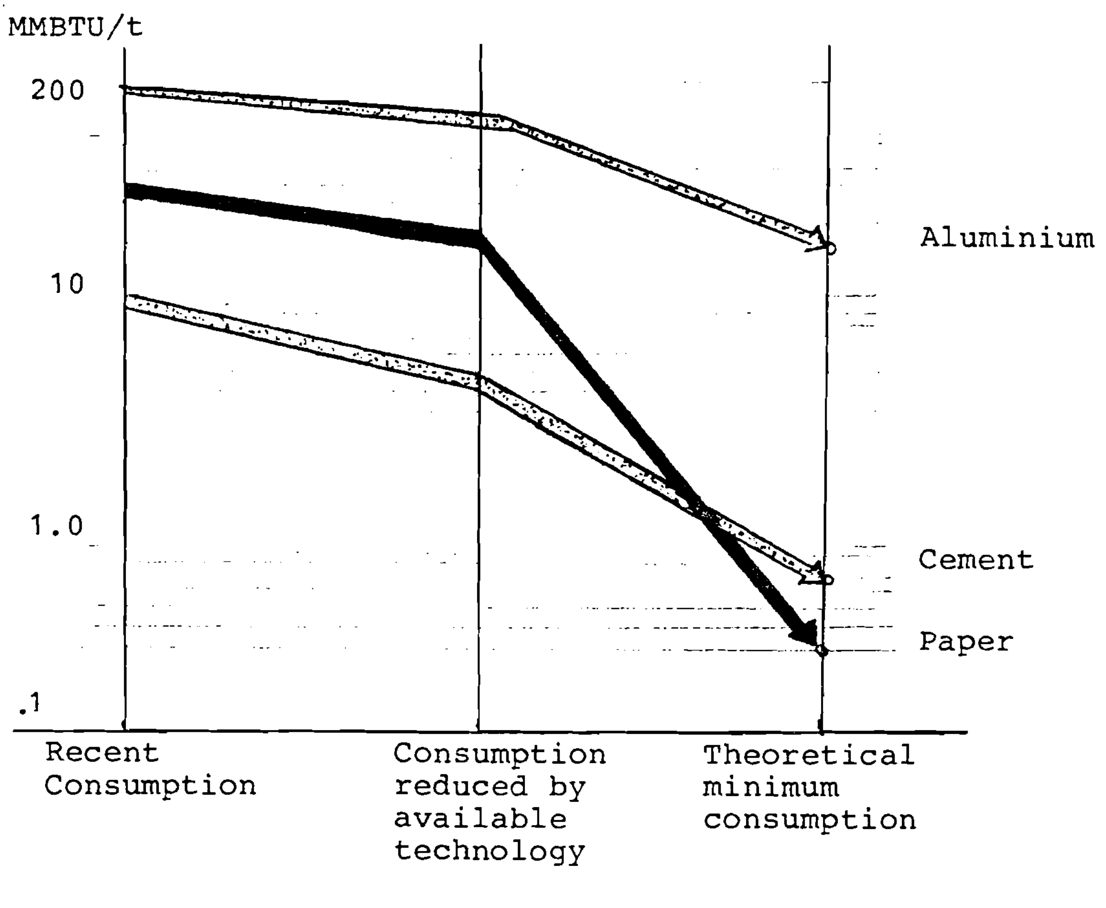

Figure 5. Energy savings potentials in some industries.
(Kairamo 1980)

NEW PROCESSES

The use of energy in different subprocesses in the pulp and papermaking differs very much as can be seen from Table 4. This table also clearly indicates what are the key-areas for new more energy efficient processes: in the pulping area drying, evaporation, bleaching and cooking, in paper making paper machines (forming and drying sections) and groundwood (or TMP) production. But as I mentioned already, energy saving is only one aspect among other targets (decrease of capital costs, higher yield, decrease of environmental load, safety, new raw materials, better quality, saving in chemicals, lowering of other operating costs etc.); and so in many cases the energy savings alone can not justify the criteria for the implementation of the investment suggested.

There are many new processes under different stages of development and technical maturity. Table 5 gives an overview of some of them. From the new processes mentioned in the table some are very energy saving; the closed mill concept, displacement bleaching and washing and the new forming and drying methods just ot mention a few. A very interesting idea in the pulping area is the so called autocausticization process lately intensively studied in laboratory scale. (Jansson 1979). In this process the need of a lime kiln could be totally eliminated and as mentioned earlier a lime kiln in a modern kraft pulp mill is the only subprocess needing external energy. However the new autocausticizing pulping process is just at the early stages of development and for example, the question of additional chemical costs has not be clarified. The potential savings in heat and electric energy achieved by displacement bleaching in comparison with the conventional bleaching sequence can be 40-50% or even higher (Gullichsen 1977). However with several process technological improvements and changes, (e.g., closing at the circulations, use of ClO_2, high consistency in chlorination etc.) the heat and power consumption also in conventional sequence can be remarkably decreased. There are also a lot of new cooking methods under different stages of development and it is to be expected that the specific heat consumption also in the digesting area can be lowered in the future.

About 25-40% of the total energy consumption in the manufacture of market pulp, paper or paperboard is associated with the removal of the water (mechanically or thermally) in the forming and drying processes. It is thus very clear that remarkable attention has been given to new means and methods in these areas in order to reduce the energy consumption. Some newest ideas here are press drying, (Slinn 1979) and dry forming, (Attwood, Sparkes 1980). Mill-scale runs with dry forming have given totally 40-60% savings in energy consumption in comparison with the conventional processes starting from dry fiber. However, there are still many unsolved problems associated with these new processes.

Table 4. Typical distribution of energy consumption.

BLEACHED KRAFT PULP	
Area	Percentage from total energy
Evaporation	26
Drying	25
Cooking and washing	18
Bleacing	12
Recovery and power plant	10
Screening	2
Wood handling and effluent handling	2
Miscellaneous	5
NEWSPRINT	
Area	Percentage from total energy
Paper machine	64
Grinding	21
Pulp handling	7
Power plant	6
Miscellaneous	2
INTEGRATED WHITE PAPER	
Area	Percentage from total energy
Paper machine	27
Digesting and washing	15
Chemicals recovery and power plant	14
Bleaching	13
Evaporation	12
Refining	5
Wood handling	3
Miscellaneous	11

Table 5. New Processes

AREA / PROGRESS	WOOD HANDLING	DIGESTING	RECOVERY	WASHING & CLEANING
Idea or Laboratory	Pipe line chip transportation	Biological pulping Hydrotropic pulping	Autocausticiza-tion	
Pilot plant	Steam impregna-tion and bark removel	Biological and oxygen pulping Biological and TMP Anthraquinone pulp-ing	Pyrolysis recovery	
Commercial (some appli-cations)	Whole tree chipping	Polysulphide pulp-ing	Fluidized bed recovery	Displacement washing Raphson closed mill
Standard	Dry debarking	TMP Pressure GW Solvent deinking		

AREA / PROGRESS	BLEACHING	STOCK PREPARATION	FORMATION	DRYING
Idea or Laboratory	Electrolytic bleaching O_3--bleaching		"Dry" papermaking process	"Dry" papermaking process
Pilot Plant	Vapor phase bleaching Chloride-free bleaching	Chemical beating	Dry Forming	High intensity press Extended nip press Fluidized bed drying Pressure drying
Commercial (some appli-cations)	Displacement bleaching Raphson closed mill		High consistency forming	Double felt, Vac drying
Standard	Oxygen bleaching		Twin-wire converted flow forming	Flash drying Air drying

Another remarkable change which might also save a lot of both fibre and energy would be the increasing use of recycling; therefore, more effective collection systems and deinking processes are needed.

PROCESS CHANGES AND IMPROVEMENTS

In this category I include for example the following measures:

- -- building of cogeneration with back pressure turbines
- -- using of bark
- -- wood waste and hogged wood as fuels in power boilers
- -- building of recovery systems in sulfite pulp mills
- -- adding a new set (concentrator) in evaporation
- -- closing of the circulations in the bleaching sequence
- -- improvements in the use of secondary heat (heat ex-exchangers, scrubbers etc.)
- -- closing of the circulations in the paper machine
- -- better forming and pressing equipment
- -- high consistency refining
- -- chemical beating
- -- closing of screening and washing systems
- -- dry debarking
- -- changes in the quality targets of the endproducts (not too high quality; requirements according to the end use of the product)
- -- use of wood as fuel in lime kiln
- -- better dimensioning and use of pumps and fans (speed control) etc.

With these modifications remarkable savings in energy consumption (in addition to other improvements) with a smaller investment can be achieved.

On the other hand new and stronger demans on environmental protection will to some extent increase the enery consumption in the pulp and paper industry. Examples from new equipment or processes for environmental protection are:

- -- extra washing stages in pulp mills
- -- white water tanks
- -- third chamber in the electrostatic precipitator
- -- condensate stripping
- -- scrubbers
- -- sedimentation process

-- aeration

-- chemical purification etc.

According to Norrström and Widdell (1977) the energy demand for environmental protection in a non-integrated bleached pulp mill are:

-- heat 1.4 GJ/t

-- power 36 kWh/t.

These are about 10% and 5% from the total consumption respectively. The burning of waste gases collected from cooking, washing and bleaching areas in recovery boilers or in lime kiln can on the other hand improve the energy balance a little.

CONTROL SYSTEMS

In accordance with the process modifications and additions mentioned above there will, normally, also be some improvements in the process automation, monitoring and control systems. Of course, computer control systems and other more advanced automation technology has been largely applied in the pulp and paper industry in recent years also independently from the above process changes and modifications. In addition to these process control systems special energy management and optimization systems (Kaya and Keyes 1980) and production planning and other mill-wide coordination systems have been developed and applied in the pulp and paper industry (Uronen 1980). I will not discuss the equipment, theory, methodology or algorithms used in these energy management systems; these details can be found for example in a recent survey by Kaya and Keyes (1980). The potential energy savings achieved by the different computer control and coordination systems have been listed in Table 6. The data presented is based on some published reports (Al-Shaikh 1978, Elsilä 1979, Fam 1980, Gee and Chamberlain 1977, Hyväri 1973, Kairamo 1980, Keyes 1975, Leffler 1980, Paasila and Reynolds 1977, Peterson and Rückert 1978, Uronen 1978, Valkama 1975)and on the experience and estimates of the author. We can see that the potential for remarkable savings in energy consumption with the aid of more advanced control systems is there, and it is to be expected that the number of these systems will rapidly increase in the coming years. Of course the process computer systems will have many other benefits and savings in addition to the energy savings i.e., higher capacity, savings in raw materials and chemicals, better and a more even quality of the products, a decrease in the losses and environmental load, better safety, easier operation, effective monitoring and reporting etc.

It is to be noted here that not all savings listed in Table 6 can be obtained at the same time at the same mill; the savings actually obtained are highly dependent on the situation of the mill in question (equipment, operational practices, level of automation etc). In this connection I would also like to point out that in speaking about the energy management systems perhaps one of the biggest advantages of these systems is that with it

Table 6. Energy savings with the computer control systems

AREA OR PROCESS	ENERGY SAVINGS POTENTIAL IN UNIT PROCESS	ENERGY SAVINGS POTENTIAL IN WHOLEMILL BALANCE	NOTES
Batch digesting	8-30%	2-5%	
Continuous digesting	0-2%	0-0.5%	Indirect
Bleaching	8-12%	0.5-1.0%	
Recovery boiler	3-5%	0.5-1.0%	Decrease in soot-blower steam usage Improvement of thermal efficiency 3-5%
Auxiliary boiler	10-20%		Improvement of thermal efficiency 3-5% More base fuel can be used
Evaporation	5-6%	1.5-2.0%	
Lime kiln and causticization	10-20%	1-2%	
Drying of pulp	5-10%	1-2.5%	
TMP	3-5%	2-3%	newsprint
SG	3-5%	2-3%	newsprint
Stock preparation	3-5%	1-1.5%	
Paper machine	4-10%	2-5%	
Production planning		0-2%	
Energy optimization		5-10% 2-3%	without unit control systems with unit control systems

When all the above is observed then the toal savings potential in integrated mills is 15-30%

the operational management and operators know exactly and in realtime how we generate, consume, purchase and distribute energy in its different forms around our mill complex and the prices and cost factors must be included in this information. This consciousness will be the first step towards energy efficiency in the mill. The various types of computerized systems in order to be useful and effective must be properly maintained and updated and also special attention must be put on the training of the personnel at each level of organization using these systems.

SUMMARY

We all know that pulp and paper is a very energy intensive industrial branch. The operational practices and also prices of different sources of energy vary remarkably from country to country and even from mill to mill. However, after the oil embargo 1973/74 this industry as well as all other energy-intensive industries has invested plenty of capital for energy saving technology and has also tried by other means to decrease the energy bill of the mills. Remarkable results have already been achieved and the average energy self-sufficiency of the pulp and paper industry in most industrialized countries is about 50%. But theoretically and even by using the best available technology of today it is possible to reach a much higher self-sufficiency; in some products even a total self-sufficiency. I believe that during the 1980's there will be built, for example, market pulp mills which are 100% energy self-sufficient. However the capital investments needed for renewing the existing equipment and modernizing the older mills are so great that the average mills will still need a lot of purchased fuels and electricity as energy sources during the eighties. However, in all cases and in every mill there will be a continuous fight against the wasting of energy and a struggle for a more efficient use of energy which will be a central task for engineers in the pulp and paper industry and not least for the control and systems engineers. It is the opinion of the author that by the extensive use of modern automation and systems engineering it is possible to decrease remarkably the unit energy consumption and thus reach a higher energy self-sufficiency with moderate capital investments.

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