# THE ENERGY EFFICIENT PULP MILL – TODAY AND IN THE FUTURE

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## Summary

Different methods to improve the energy efficiency for a new market Kraft Pulp mill are discussed and are compared with a model mill using conventional technique.

A full scaled market pulp mill using conventional technique will use about 10,8 GJ/ADtB for process and 4,0 GJ/ADtB for power generation. By using available commercial technique the heat consumption in the process departments can be reduced to 9,8 GJ/ADtB. The heat consumption for power generation will then increase accordingly to 5 GJ/ADtB. By recirculation more steam through the turbo generator by increased air pre-heating etc more power will be generated. All together this will result in that the surplus of electrical power will increase from 367 kWh/ADtB to 463 kWh/ADtB.

The surplus of power can be improved further by increasing the recovery boilers steam data and by using feed water for attemperation of steam in between the superheaters instead of using sweet water condenser. These measures will increase the surplus with 25 and 10 kWh/ADtB respectively.

The use of fossil fuels can be reduced significantly by using bio-mass firing in the lime kiln. About 1/3 of the lime kilns heat demand can be replaced by bio-mass generated at the mill (debarking in the forest). This correspond to about 16 000 t/a of fuel oil.

In existing mills some of the measures can be used to improve the energy efficiency, such as pre-heating of demin water, variable speed drives. However, it is important to keep in mind that heat savings are only interesting if there is an alternative use for the heat e.g. possibility to sell bark, increase the condensing power generation etc. On the other hand savings of electrical power are always of interest.

## Summary in Portuguese

São discutidos diferentes métodos para melhorar a eficiência energética de uma fábrica nova de celulose Kraft de mercado e comparados com um modelo que utiliza a técnica convencional.

Uma fábrica completa de celulose de mercado utilizará 10,8 GJ/ADtB no processo e 4,0 GJ/ADtB para geração de energia elétrica. Usando-se melhorias técnicas disponíveis é possível reduzir o consumo de calor no processo para 9,8 GJ/ADtB acarretando uma disponibilidade correspondente de calor para geração de energia de 5 GJ/ADtB. Passando-se mais vapor pelos turbo geradores pelo aumento do aquecimento de ar para a caldeira, etc., mais energia elétrica será gerada. Todas as medidas em conjunto resultarão em que o excedente de energia elétrica passará de 367 kWh/ADtB para 463 kWh/ADtB.

O excedente de energia pode ser melhorado ainda mais aumentando-se as características do vapor gerado e utilizando-se água de alimentação para atemperação do vapor superaquecido ao invés de condensado do condensador Dolezal. Estas medidas aumentarão o excedente em 25 e 10 kWh/ADtB respectivamente.

O uso de combustíveis fósseis pode ser reduzido significativamente queimando-se biomassa no forno de cal. Cerca de 1/3 do calor necessário no forno de cal pode ser substituído por biomassa gerada na fábrica preparação de madeira para o processo (considerando-se descascamento na floresta). Isto corresponde a aproximadamente uma economia de 16 000 t/a de óleo.

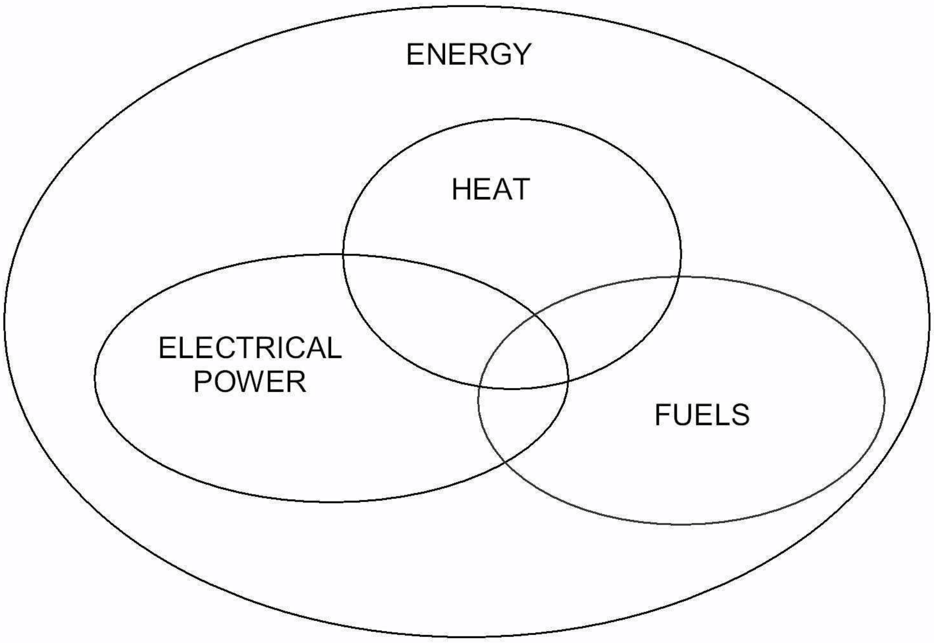
Em fábricas existentes algumas das medidas podem ser utilizadas para melhorar a eficiência energética, como pré-aquecimento de água desmineralizada, uso de variadores de velocidade, etc. Entretanto, é importante estar ciente de que economia de calor só é interessante se houver

alternativas para uso do calor economizado como, por exemplo, vender biomassa, aumentar a geração em condensação, utilização em outras áreas da fábrica substituindo fontes de energia mais caras, etc. Pelo contrário, a economia de energia elétrica é sempre interessante.

Key words: energy efficiency, specific consumption, specific energy generation, heat generation, power generation, heat saving, power saving, heat, power, fuel.

# INTRODUCTION

The energy consumption (in this document the expression energy is used for heat, electrical power, fuels etc, see the picture below) in the pulp and paper industry has changed significantly during the last 30 years. Firstly, expensive fuel oil was replaced with biomass and by recovery of secondary heat. Presently, the energy focus in the Kraft Pulp Mill is to improve the power generation and sell more power to the grid.




As an example the, heat consumption for market pulp in Sweden has as an average gone down from 17,3 to 14,4 GJ/ADtB during the period of 1979 - 2007. This is a reduction with 2,9 GJ/ADtB or 17%. During the same period the power consumption has decreased from 846 kWh/ADtB to 800 kWh/ADtB. It can also be mentioned that the internally generated power has increased from 508 to 643 kWh/ADtB. The improved energy efficiency has mainly two reasons:

- The pulp production has increased from about 2 to 3,7 MADtB/a and the remaining mills are bigger which normally reduce the specific consumptions.
- Increased prices for fuel oil and electrical power.
- In 2005 the Swedish government implemented a voluntary program for energy savings in the energy intensive industry. The participants got tax benefits for consumed electrical power and the Swedish government was expecting energy savings corresponding to the reduction in tax.

A low heat or power consumption is not necessarily an indication of an energy efficient mill. An energy efficient mill produce, generate and utilize the energy in a cost efficient and environmental friendly way. With other words generate maximum possible of back-pressure power from internal fuels and utilize a minimum of fossil fuels and at the same time have low specific consumptions of heat and electrical power.

In this paper the energy efficient pulp mill is discussed, today and in the future by implementing a number of different measures to the present situation of the model mill. The paper is concentrated on hardwood market Kraft Pulp mills as those are the most common ones in Brazil and represent by far the biggest tonnage in Brazil.

## THE PRESENT ENERGY SITUATION IN MODERN PULP MILLS IN BRAZIL AND ABROAD

A modern market and non-integrated Kraft Pulp Mill is normally self sufficient with energy from black liquor for heat and power generation, regardless of location and wood spice. However, fossil fuels are used for start-up/shut-down and in most cases also in the lime kiln.

The typical configuration for the latest installed full sized market pulp mills are:

- Annual production > 1 000 000 ADtB/a
- 6-effect evaporation train in Brazil and 7-effect abroad
- Boiler steam data 86-93 bar and 480 – 490 C in Brazil. Above 100 bar and 500 C in Europe and USA.
- Steam turbine with or without condensing tail depending on mill configuration.
- Power boiler to handle at least the internally generated biomass. In expansion projects it has lately been common not to install any additional power boiler capacity.

The *average* specific heat consumption are summarized in table 1 below:

| Table 1 | | Brazil | Abroad |
|---|---|---|---|
| Heat consumption process excl. soot blowing steam | GJ/ADtB | ~9,9 | 9,4 – 9,6 |
| Heat consumption for power generation, incl. power boiler | GJ/ADtB | 4,4 – 4,7 | 2,8 – 5,1 |
| Ditto excl. power boiler | GJ/ADtB | 3,7 – 4,1 | 2,8 – 3,7 |

The main difference in heat consumption for process can be explained by the fact that the Brazilian mills' have 6-effect evaporation plants and the ones abroad in most cases have 7-effects. It shall also be noted that all of the mills have more or less the same steam data and are without feed water preheating and elevated combustion air temperature.

The *average* power generation and consumption are summarized in table 2 below:

| Table 2 | | Brazil | Abroad |
|---|---|---|---|
| Power consumption excluding chemical plants | kWh/ADtB | 500 - 520 | 560 - 600 |
| Power generation including power boiler | kWh/ADtB | 700 - 820 | 740 - 890 |
| Surplus of power with power boiler | kWh/ADtB | 200 - 300 | 180 - 290 |
| Power generation excluding power boiler | kWh/ADtB | 655- 720 | 700 - 740 |
| Surplus of power without power boiler | kWh/ADtB | 155 - 200 | ~140 |

The following conclusions can be made:

- Brazilian full sized mills have a lower specific power consumption than the ones abroad
- The surplus of electrical power is higher from Brazilian mills than the ones abroad

Furthermore it can be assumed that new Brazilian mills have a potential to reduce the heat consumption to at least the same level as for the mills abroad. The reduced heat consumption could be used for increased power generation or reduced power boiler load or even eliminating the power boiler.

The latter could be interesting if there is an alternative use for the biomass that otherwise should be fired in the power boiler.

Below are discussed some methods and measures to reduce the heat consumption and/or increase the power generation, with other words how to improve the energy efficiency.

## OPPORTUNITIES – FOR THE FUTURE

It can be assumed that the energy situation will improve for new pulp mills in Brazil as well as abroad. The reasons for this statement are:

- Bigger mills, which normally reduce the specific consumption of both heat and power
- Increased value of exported electrical power
- Increased cost for purchased biomass fuels
- Increased costs for purchased fossil fuels
- Environmental friendly approach
- New and improved technology

In this paper the future Kraft Pulp mill will have the following key-data as a reference case:

- Annual production at 1 500 000 ADtB bleached from Eucalyptus
- The wood is debarked in the forest
- Specific dry solids generation 1,35 tDS/ADtB
- Weak black liquor at 14% DS and firing liquor at 80% DS virgin
- Demin water preheated in the evaporation plant to 45 C.
- Power boiler will not be installed
- One or two turbines, at least one with condensing tail
- Chemical supply is over the fence and the consumption of power is not included in the mills consumption
- Drying machine operating with low pressure steam
- 6-effect evaporation train
- Surplus of power can be exported to market price without any limitations
- Fuel oil or natural gas firing in the lime kiln

All discussions below are based on the configuration above. This means that the reference case mill will have the following estimated specific heat and power values for generation and consumption at *MCR*:

| Table 3 | | Specific heat / power |
|---|---|---|
| Heat generation from black liquor | GJ/ADtB | 14,8 |
| Process consumption | GJ/ADtB | 10,8 |
| Heat consumption for power generation | GJ/ADtB | 4,0 |
| Power generation | kWh/ADtB | 865 |
| Power consumption, excluding chemical plants | kWh/ADtB | 498 |
| Surplus of electrical power | kWh/ADtB | 367 |

Please note that the figures above only should be seen as illustrative examples for the discussions below regarding potential for improvement of energy efficiency.

It is important to keep the following in mind:

- The heat input to the system is constant; the only boiler in the energy system is the recovery boiler with the same input of liquor for all studied options.
- A saving of heat (steam) will increase condensing power generation, but only with the part from the actual pressure level down to the condensing level. Furthermore all of the saved steam will not pass to the condenser as some additional steam will be needed in the feed water tank to reheat the additional flow of condensate.
- Increased steam consumption for air preheating, feed water preheating etc, will reduce the steam flow to the condensing tail and by this reduce the power generation. However, this type of measure will increase the steam flow from the boiler and more steam will circulate through the turbo generator down to the level for the increased consumption and consequently more back-pressure power will be generated. The net result will be positive.

## Increased boiler steam data to improve power generation

In Brazil the steam data for new boilers have been 86-93 bar and 480 – 490 C with one exception, the new recovery boiler at Klabin´s Monte Alegre mill which is operating at 101 bar(a) and 500 C.

In North America and Europe most of the latest boilers have been designed with a pressure just above 100 bar and temperatures just above 500 C.

It is important to keep in mind that the chlorine and potassium content in the Brazilian liquors normally are much higher than in the European and the North American ones. This is most likely the main reason for the difference in steam data.

The reason to increase the steam data is to improve the power balance. Below table 4 shows an estimation of the impact on the power balance, the increased power consumption for feed water pumps are taken into account.

| Table 4 | Steam data increase | |
|---|---|---|
| | from | To |
| Pressure bar(a) | 93 | 105 |
| Temperature C | 490 | 505 |
| Increased specific power generation kWh/ADtB | 25 | |

As can be seen the improvement in specific power generation is quite significant. However, the increased cost for the higher design data for the recovery boiler including more sophisticated material in the superheater is also quite significant and should be justified by the revenue from the increased power generation. If the higher steam data are profitable or not must be evaluated case by case and from time to time as both the cost for electrical energy and alloyed tubes vary from time to time. Therefore the steam data used as reference is assumed to remain at the present level for mills in Brazil i.e. 93 bar(a) and 490 C.

## Soot blowing steam as extraction steam from the turbo generator

Use of external soot blowing steam is today a common practice. For the latest projects a reduction from about 30 bar(g) to about 18 bar(g) have been discussed. According to one of the major soot blower suppliers, two mills in the US are operating with only 14 bar(a) at the poppet valve. The steam consumption has been reported to be the same as with a higher pressure at the poppet valve. In practice this means that the pressure at the turbines extraction for soot blowing steam can be reduced from about 30 bar(a) to about 20 bar(a). The impact on the power generation can be seen in table 5:

Table 5

| Decreased soot blowing steam pressure at turbine | | Increased surplus of power |
|---|---|---|
| From | To | |
| 30 bar(a) | 20 bar(a) | 5,1 kWh/ADtB |

The improvement in specific power generation is quite modest. However, the investment cost is low and therefore the reduced pressure level for the soot blowing steam is of economical interest and a simple way to improve the mill’s energy efficiency.

## Reduced steam data at the consumers

One way to increase the power generation is to reduce the steam pressure level at the steam header for consumers. By this more back-pressure power and less condensing power will be generated. The net result will be positive.

For the MP-steam system the pressure level has traditionally been 12-14 bar. However, in new mill’s the tendency has been to reduce the pressure down to the level of 9 bar(a) without any major impact other than bigger heat exchangers etc. This measure will increase power generation and the mill´s surplus of power as shown in table 6 below.

Table 6

| Decreased MP-steam steam pressure at the consumers | | Increased surplus of power |
|---|---|---|
| From | To | |
| 12 bar(a) | 9 bar(a) | 7,8 kWh/ADtB |

Also in this case the impact on the mill’s power balance is modest but the measure has been evaluated in different projects and the impact on the project economy is positive.

The pressure level in the LP-steam system is already at a quite low level and it will be difficult to reduce that further as the evaporation plant as well as the pulp dryer normally dictates the pressure level. To introduce one more pressure level will most likely be too costly.

## Feed water preheating

The steam flow from a boiler is a function of the feed water temperature. With the same heat input and the same steam data more steam will be generated with a higher feed water temperature. With a higher steam flow through the steam turbine more back pressure power and less condensing power will be generated. The net impact on the power generation will be positive.

By tradition the feed water temperature for recovery boilers has been chosen to 115 – 130 C. In the power industry the feed water temperature is normally much higher. The reason for the low feed water temperature to the recovery boiler has been the boiler efficiency. With higher temperature the flue gas temperature will be higher but not as much as the increase of feed water temperature.

Feed water preheating can be done in many different ways but for the recovery boiler mainly two options are at hand:

- Increased temperature on feed water to the economizer by increasing the temperature in the feed water tank.
- Increased temperature on feed water to the economizer by pre-heating with external preheater before the economizer.
- Heating of feed water with external heater between economizer 1 and 2 or after economizer 2.

Of course the feed water preheating can also be done as a combination of the options.

Pre-heating of the feed water before the economizer will increase the flue gas temperature and the boiler efficiency will be somewhat lower. The same will happen with pre-heating after economizer 1 and is not further discussed. Heating of the feed water after economizer 2 will not affect the flue gas temperature, but the possibility might be limited due to high temperature after the sweet water condenser.

In new pulp mills the following configuration is foreseen:

- Operating the feed water tank at as a high temperature as possible using LP-steam. With other words the control valve for steam fully open
- MP-steam preheater before the economizer. This will increase the feed water temperature to around 160 C.
- With reduced pressure on the soot blowing steam this steam cannot be used in a preheater after the sweet water condenser as the temperature is not high enough.

An increase of the temperature in the feed water tank can in most cases be done without any investment cost. In table 7 below the increase in power generation is estimated. It should be noted that the loss in boiler efficiency as well as increased power consumption for ID fans is taken into account in the calculations.

Table 7

| Increase of temperature in the feed water tank | | Increased surplus of power |
|---|---|---|
| From | To | |
| 130 C | 140 C | 3,1 kWh/ADtB |

The impact on the power generation is modest. This is due to the fact that less condensing power will be generated. In the case with only back pressure turbines (with integrated paper mill) the surplus will be much higher; however the fuel consumption will also increase.

Installation with an external feed water preheater before the economizer 1 or in between the two economizers will make it possible to further increase the feed water temperature. In table 8 below the estimated increase in power generation is shown.

Table 8

| Increase in feed water temperature | | Increased surplus of power |
|---|---|---|
| From | To | |
| 140 C | 160 C | 2,3 kWh/ADtB |

The calculation above includes the lower efficiency of the boiler as well as the increased power consumption due to higher flue gas temperature. The increase in power generation is low for the same reasons as above. However, the measure is easy and not too costly to implement and has been verified to improve the project profitability.

It shall be noted that there are potential to utilize the sensible heat in the flue gases and by this improve the economical profitability of the feed water preheating.

REPLACING SWEET WATER CONDENSATE WITH INJECTION OF FEED WATER

By replacing the sweet water condenser by using feed water for attemperation of the steam between the superheaters even a higher feed water temperature could be achieved installing a feed water preheater in between economizer 2 and the drum. The boiler will generate more steam and more steam will circulate through the turbine and this will result in a higher power generation. Using the same pressure level as the soot blowing steam the following could be achieved with an incoming feed water temperature at 140 C, see table 9 below:

Table 9

| Increase in feed water temperature after eco 2 | | Increased surplus of power |
|---|---|---|
| From | To | |
| 230 C | 260 C | 10 kWh/ADtB |

This kind of systems is commonly used in utility plants and there is no technical reason why it should not be possible to keep the feed water quality on a high stable level also at a recovery boiler. The investment cost will be very low if any as the sweet water condenser is replaced with the feed water pre-heater.

## Combustion air temperature

The steam generation in a boiler is a function of the heat input. With the same heat losses and the same steam data more steam will be generated with a higher combustion air temperature. With a higher steam flow through the steam turbine more power will be generated.

The combustion air temperature has by tradition been in the range of 120 – 150 C for a recovery boiler’s primary and secondary air levels. In recent projects in Europe and North America the combustion air temperature has been increased significantly. No negative impacts on the emissions are reported as well as any negative impacts on the boiler operation in general.

In recent projects, boiler makers have suggested an increase of the combustion air temperature for all air levels to around 180 – 190 C by using also steam with the same pressure as the soot blowing steam for air preheating. However, there are no technical reasons why the temperature level could not be increased further for the levels using fresh air. For the DNCG it is recommended to keep the maximum temperature around 180 C to minimize the risk for self ignition of explosive compounds.

For the reference mill the impact on the power generation will be as shown in table 10 below.

Table 10

| Increase in combustion air temperature | | Increased power surplus |
|---|---|---|
| From | To | |
| Primary and secondary air 150 C. tertiary air at ambient temperature | For all air levels except DNCG 210 C | 14,5 kWh/ADtB |

This measure will as can be seen give a significant improvement in the energy efficiency. The impact on the investment cost is has been studied and the conclusion is that combustion air preheating to higher temperatures than today has a positive impact on the projects over-all economy. With other words the pay-back for the combustion air preheating is shorter than for the project in general.

## Demineralized water temperature

Preheating of demineralized water is a direct way to reduce the energy consumption or at constant boiler load increase the condensing power generation.

Traditionally in Europe waste heat streams have been used to increase the demin water temperature.

Examples on such streams are:

- Continuous blow-down from the boilers
- Hot water from flue gas scrubbers / condensers
- Hot water from vent gas scrubbers / condensers

In Brazil the demin water normally is at ambient temperature or preheated in the evaporation plant to around 40 C.

If the mill is using a mixed bed condensate polisher it is difficult to increase the demin water temperature above 40 – 45 C as the demin water is heat exchanged with the return condensate before the mixed bed polisher. The maximum operating temperature for these is 50 C. However, if the mixed bed polisher is replaced with a strong cat ion exchanger the temperature can be raised to 110 - 120 C. However it might be necessary to increase the blow-down from the normal level of 0,5% to 2% to keep the silica at acceptable levels for the turbo generator. This of course is dependent of the silica content in the return condensate.

Using heat from the vent gas scrubber / condenser a demin water temp of about 60 C can be achieved. The measure will reduce the LP-steam flow to the deaerator. As the mill is more than self-sufficient with heat more steam will be available for the turbo generators condensing tail. The impact on the power balance can be seen below in table 11.

Table 11

| Increase in demin water temperature | | Increased surplus of power |
|---|---|---|
| From | To | |
| 40 C | 60 C | 8,9 (1,9) kWh/ADtB |

The value within brackets is for a blow-down at 2%. The cost to implement this measure will be very small if any as the installation will replace the heat recovery from the evaporation plant or other source used to heat the demin water to 40 C.

Further increase can be achieved by using sensible heat in the flue gases to heat the demin water. Also in this case the measure will reduce the LP-steam consumption in the deaerator and more steam will be available for the turbo generators condensing tail. The impact on the power balance can be seen in table 12 below.

Table 12

| Increase in demin water temperature | | Increased surplus of power |
|---|---|---|
| From | To | |
| 60 C | 100 C | 13,8 kWh/ADtB |

Also in this case the cost will be very small if any as the measure can replace both the heat recovery from the evaporation plant and the heat recovery from the vent gas scrubber.

## Hot weak black liquor to the evaporation plant

With a modern digester technology the weak black liquor temperature is normally in the range of 115 C after internal heat recovery. However, the evaporation plant has for economical reasons an atmospheric weak black liquor tank and therefore the weak black liquor is cooled to about 90 C in the cooking plant before sent to the evaporation plant.

In recent projects it has been discussed not to cool the weak black liquor and instead flash the liquor in a number of steps in a flash column located in evaporation plant before being stored in an atmospheric tank. The evaporation plants surface condenser will also be used to condense the flash steam in case the evaporation plant is out of operation. The flash steam will be added at different locations in the evaporation plant. With this solution a 6-effect evaporation train will have more or less the same steam economy as a 7-effect train. The impact on the power generation is shown in table 13 below.

Table 13

| Increase weak black liquor temperature from digesters | | Increased surplus of power |
|---|---|---|
| From | To | |
| 90 C | 115 C | 14,5 kWh/ADtB |

The increased investment cost for the more complex installation have been studied and compared with the increased power generation. The conclusion is that this measure will increase the over-all project economy.

## 7-effect evaporation plant

In countries with high cost for fuels and with mills that are not self sufficient with heat, 7-effect evaporation trains are common. In more recent years mills self sufficient with heat have started to install 7-effect evaporation trains to increase the power generation. In Brazil there is only a few 7-effect trains in operation the rest of the evaporation plants have 6-effect trains.

With a 7-effect evaporation train the LP-steam consumption will be reduced compared with a 6-effect train. Theoretically this reduced steam consumption can be used to:

- Lower the power boiler load. In a market pulp mill this is not an option as the mill is self sufficient with heat from only the recovery boiler.
- Increase the condensing power generation

In the table 14 below is shown the impact on the reference mill's power surplus (including the power consumption for the 7-effect) by installing a 7-effect train instead of a 6-effect evaporation train.

Table 14

| Change of evaporation plant concept | | Increased surplus of power |
|---|---|---|
| From | To | |
| 6-effects | 7-effects | 25,6 kWh/ADtB |

Recent studies have shown that the pay-back is less than 3 years for the 7-effect evaporation train compared with a 6-effect installation.

## Biomass firing in the lime kiln

To replace fossil fuels in the lime kiln with firing some kind of biomass firing will have some obvious benefits such as:

- Reduce the cost for handling fines and bark generated at the mill.
- Environmental friendly as fossil fuels is replaced with a “green” fuel
- Low operating cost as the biomass in many cases has no alternative use.

There are at least three different options regarding biomass firing in the lime kiln, one indirect method and two direct methods.

- Lignin: the lignoboost process (Metso) removes part of the lignin ( <25%) from the black liquor and gives as a result a lignin powder that after drying can replace the fossil fuels in the lime kiln.
- Gasified biomass (Andritz and Metso): Dried biomass can be gasified and utilized in the lime kiln replacing up to 100% of the fossil fuels.
- Biomass powder (Andritz and Metso): Biomass can be dried and grinded and utilized in the lime kiln replacing up to 100% of the fossil fuels.

The Lignoboost process is at present not installed in full scale at any mill. However, the Södra Cell Mörrum mill has applied for grants from the Swedish government to help financing the first full scale plant.

For a typical Brazilian mill the lignin from the lignoboost process could replace all fossil fuel in the lime kiln. However, the steam generation in the recovery boiler would at the same time be reduced and consequently also the power generation.

Both firing of gasified biomass and biomass powder are carried out in commercial scale in different mills. The main problems have been the dryer system. However, the technique has developed and today the availability is expected to be higher.

With debarking in the forest the amount of biomass generated at the mill corresponds more or less to 1/3 of the lime kilns heat demand. As a lime kiln normally consume about 5 800 MJ/t burnt lime the annual saving will be in the range of 16 000 t/a as fuel oil 3A.

The alternative to install a biomass fired power boiler would be much more costly and will from an energy point of view be as generating condensing power with fossil fuels.

## Heat recovery in the bleaching plant.

The $ClO_2$ water from the chlorine dioxide plant normally has temperature at about 9-10C. In the most recent projects the $ClO_2$ water has been pre-heated by using secondary heat sources e.g. the effluent from the EoP stage to 45 C, replacing about 6 t of LP-steam per ton of pulp. The mixture of pulp and $ClO_2$ water is after that heated with direct steam to 90 C. The steam consumption for the second heating is around 7,6 t MP-steam per ton of pulp.

The preheating of the $ClO_2$ water is conventional technique and is already included in the reference mill.

## Consumption of electrical power

To point out some general measures to save or make the use of electrical power more efficient and at the same time quantify the savings etc in absolute terms is very difficult.

Below are some general guidelines given regarding an efficient use of electrical power:

- For low voltage drives VFD’s are normally used when appropriate, e.g. when the load varies a lot in time.

- For medium voltage drives VFD's are normally not used and the control is with hydraulic couplings. For big drives such as feed water pumps the power saving by replacing the hydraulic couplings with VFD:s could be as much as 100 kW per pump or 300 kW in total. This correspond to about 1,5 kWh/ADtB
- Design of pump system etc without too much "fat" with other words use as small margins for head and flow as possible. From a power point of view it is not a good solution to design for future production increases. However, there might be other considerations that indicate that a different design philosophy is economical interesting.
- Use automatic turn-off of electrical consumers when appropriate, e.g. lighting.

# POTENTIAL FOR ENERGY EFFICIENCY IMPROVEMENTS IN EXISTING PULP AND PAPER MILLS

The potential for energy improvement in an existing mill is very much depending on the mills age and how well in general the mill is operating.

In general terms there are a number of factors that have an impact on the potential for energy efficiency improvements:

## Mills self sufficient with internally generated fuels (black liquor, bark, fines etc) for boilers.

In this case heat savings are only interesting if:

- Steam is by-passed the turbines and the internal generated fuels can be used for some other purposes
- All steam passes through turbines and the saved internal fuels / heat can be used for some other purposes such as:
    - Sold to external user at a price level which compensate for loss of power generation
    - The heat can be utilized in existing or new turbines
    - Gasification of biomass and utilization of the gas in the lime kiln
- In general, reduction of steam consumption can result in less power generation with increased over-all energy cost
- Power savings are interesting as long as the saving can justify the investment cost

## Mills <u>not</u> self sufficient with internal fuels for boilers

Heat savings are interesting if:

- Steam is by-passed the turbines
- The cost for the heat saved is higher than the cost for loss of power generated
- The boiler plant is a bottle neck
- In general, reduction of steam consumption can result in less power generation with increased over-all energy cost
- Power savings are interesting as long as the saving can justify the investment cost

Keeping the facts above in mind, many of the energy efficiency improvement items presented above might be of economical interest, these needs to be evaluated case by case.

## CONCLUSIONS

It has been shown that the potential to improve the energy efficiency at installation of a new Kraft pulp mill is significant, both in terms of reducing the heat consumption and power consumption but more important by increasing the power generation and replacing the use of fossil fuels in the lime kiln by the use of biomass.

Below in table 15 are summarized both the present situation for a typical Brazilian modern mill and the potentials for improvement of the energy efficiency.

Table 15

| | | Present situation | Future situation with commercial technique |
|---|---|---|---|
| Heat consumption for process | GJ/ADtB | 10,8 | 10,2 (9,8) |
| Heat consumption for power generation | GJ/ADtB | 4,0 | 5,0 |
| Total heat consumption | GJ/ADtB | 14,8 | 15,2 (14,8) |
| Power generation | kWh/ADtB | 865 | 965 |
| Power consumption excl. chemical plants | kWh/ADtB | 498 | 502 |
| Surplus of electrical power | kWh/ADtB | 367 | 463 |
| Fossil fuel consumption in lime kiln | toe/a | 48 000 | 32 000 |

Please note that heat consumption includes heat for air and feed water preheating and this is the explanation to the higher total heat consumption in the future. The values in bracket are without the increased air preheating and feed water preheating. In addition to the above there is a potential of another 25 kWh/ADtB of surplus of power with increased steam data and 10 kWh/ADtB by replacing the use of sweet water condenser for generating attemperation water for the superheaters with injection of feed water.

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