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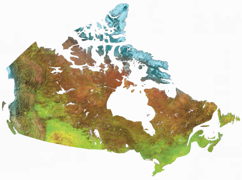

# Energy Cost Reduction in the Pulp and Paper Industry

## – An Energy Benchmarking Perspective

D.W. Francis, M.T. Towers and T.C. Browne
Pulp and Paper Research Institute of Canada
(Paprican)

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## – An Energy Benchmarking Perspective

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# Energy Cost Reduction in the Pulp and Paper Industry

**D.W. Francis, M.T. Towers and T.C. Browne**
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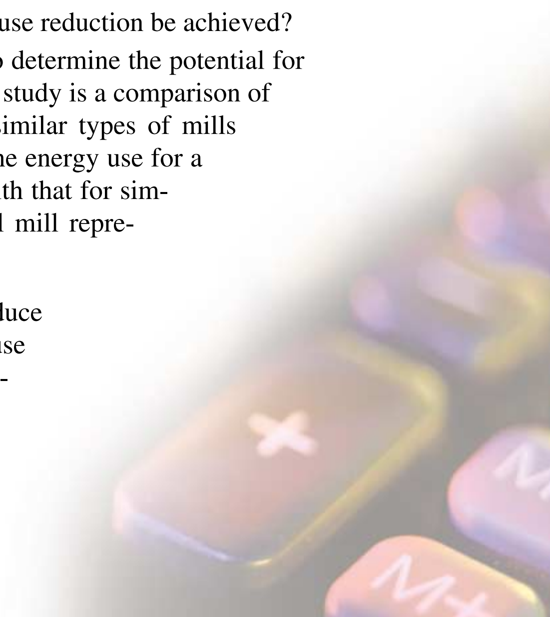
## INTRODUCTION

Energy use reduction can provide cost savings, often with low capital investment. It is a complex task, but is accessible to non-specialists with appropriate training. The Pulp and Paper Technical Association of Canada (PAPTAC) has prepared a short course on energy efficiency in the pulp and paper industry. This document discusses the motivation for developing an energy efficiency program and provides an outline of the course contents. In particular, it addresses two questions:

1. What is the potential for energy use reduction in pulp and paper mills?
2. How can this potential energy use reduction be achieved?

Benchmarking provides a means to determine the potential for energy reduction. A benchmarking study is a comparison of the competitive situation among similar types of mills producing the same product [1]. The energy use for a particular mill can be compared with that for similar mills or with that for a model mill representing the current best practice.

To illustrate the potential to reduce energy consumption and greenhouse gas (GHG) emissions, benchmarking studies were performed for the two largest production segments of the Canadian pulp



and paper industry: kraft market pulp and newsprint. In each case the energy consumption for a modern mill was determined using current proven technology and compared with that for existing Canadian mills [2].

## THE MODEL KRAFT MARKET PULP MILL

The model kraft market pulp mill produces fully bleached market pulp from wood chips transported from local sawmills. It utilizes the most energy-efficient unit operations that have been proven technically feasible. The power boiler uses hog fuel, and condensing-extracting steam turbines are used to produce electricity. The total liquid effluent from the mill would be approximately 35 $m^3$/Airdried tonne (ADt).

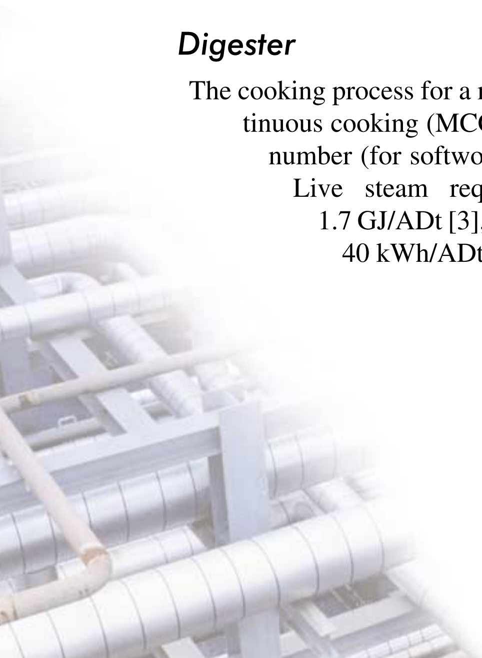
The energy consumption for the model mill is shown in Table I; the energy production is shown in Table II; and the purchased energy consumption is shown in Table III. The process design for the model mill is described in detail below.

### *Conveying Chips*

It is assumed that chips are purchased from sawmill operations. Belt conveyers would be used to transfer the wood chips from the chip piles to the pre-steaming vessel. Heat from black liquor flash tanks is used to preheat chips in the pre-steaming vessel; thus, no live steam is required. The electricity requirement for the conveying operations is estimated at 20 kWh/ADt [3].

### *Digester*

The cooking process for a modern kraft mill would be modified continuous cooking (MCC) in a Kamyr digester. The target Kappa number (for softwood) would be 30 to preserve wood yield. Live steam requirement for this process would be 1.7 GJ/ADt [3], and the total electricity demand would be 40 kWh/ADt [3].



## Table I. Modern Kraft Market Pulp Mill – Steam and Electricity Consumption

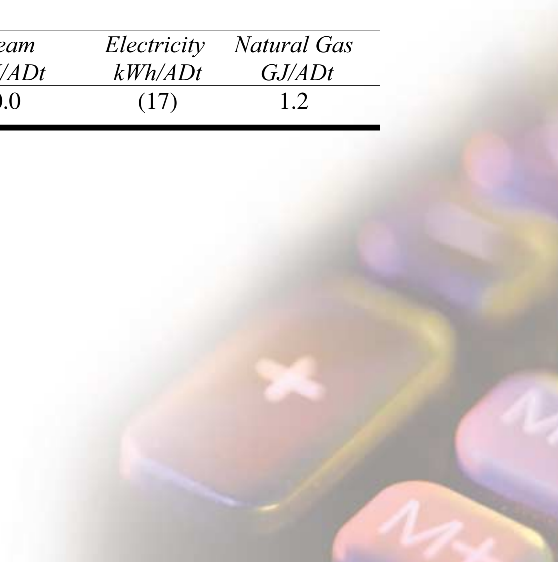
| | *Steam GJ/ADt* | *Electricity kWh/ADt* |
|---|---|---|
| Chip conveying | 0.0 | 20 |
| Digester | 1.7 | 40 |
| Washing and screening | 0.0 | 30 |
| Oxygen delignification | 0.5 | 75 |
| Bleaching | 2.3 | 100 |
| Pulp machine | 2.3 | 141 |
| Black liquor evaporators | 3.1 | 30 |
| Power plant | 2.3 | 60 |
| Kiln and recausticizing | 0.0 | 50 |
| Hot water supply | 0.0 | 32 |
| Waste-water treatment | 0.0 | 30 |
| Miscellaneous | 0.0 | 30 |
| **Total Consumption** | **12.2** | **638** |

## Table II. Modern Kraft Market Pulp Mill – Steam and Electricity Generation

| | *Steam GJ/ADt* | *Electricity kWh/ADt* |
|---|---|---|
| Recovery boiler | 15.8 | 655 |
| **Total Generation** | **15.8** | **655** |

## Table III. Modern Kraft Market Pulp Mill – Purchased Energy Required

| | *Steam GJ/ADt* | *Electricity kWh/ADt* | *Natural Gas GJ/ADt* |
|---|---|---|---|
| Amount purchased (excess) | 0.0 | (17) | 1.2 |



## Washing and Screening

High-efficiency washers, such as pressure filters, are employed for brownstock washing. Inlet consistencies for these washers is about 4 percent, more than double that of a conventional vacuum drum washer, which reduces the amount of vat dilution to be pumped. However, the blower required to pressurize the washer consumes the electrical energy savings. The net result is better washing for approximately the same energy requirement. The screen room is closed, and screening is done at 5 percent consistency. The higher consistency reduces pumping requirements. Condensate from the mill's, black liquor evaporators is used as wash water. No live steam is required for washing and screening. The electricity requirement is estimated to be 30 kWh/ADt [3].

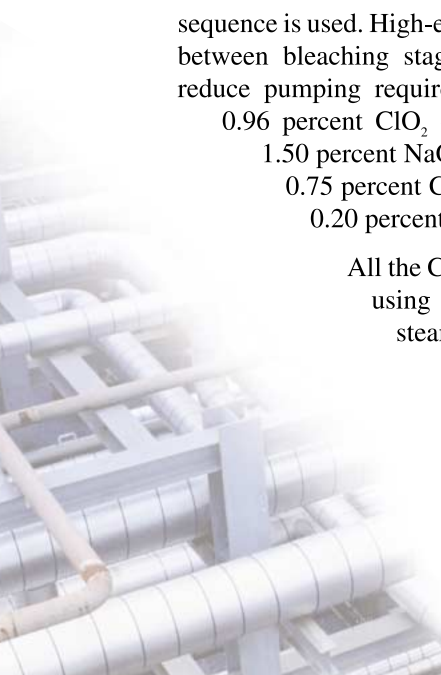
## Oxygen Delignification

Oxygen delignification is used to further delignify the pulp prior to bleaching. Approximately 60 percent delignification is achieved in two stages. Two stages of post-oxygen washing are required; twin roll presses would be used. The live steam required to heat the oxygen stages would be 0.5 GJ/ADt [3], and the electricity required for the area would be 75 kWh/ADt.

## Bleaching

A modern mill is able to achieve fully bleached pulp from a four-stage elemental chlorine free (ECF) bleach plant. A $D_0E_oD_ND$ bleaching sequence is used. High-efficiency pressure filters are used for washing between bleaching stages. All stages are medium consistency to reduce pumping requirements. The $D_0$ stage is at 60ºC and uses 0.96 percent $ClO_2$ on pulp. The $E_o$ stage is at 90ºC and uses 1.50 percent NaOH on pulp. The $D_N$ stage is at 70ºC and uses 0.75 percent $ClO_2$ on pulp. The D stage is at 70ºC and uses 0.20 percent $ClO_2$ on pulp.

All the $ClO_2$ is generated on-site from sodium chlorate using the R10 process. NaOH is purchased. The steam requirement for $ClO_2$ generation is



0.2 GJ/ADt [4]. The steam requirement for heating throughout the rest of the bleach plant is about 2.1 GJ/ADt. The electricity requirement for the bleach plant would be 100 kWh/ADt.

## Pulp Machine

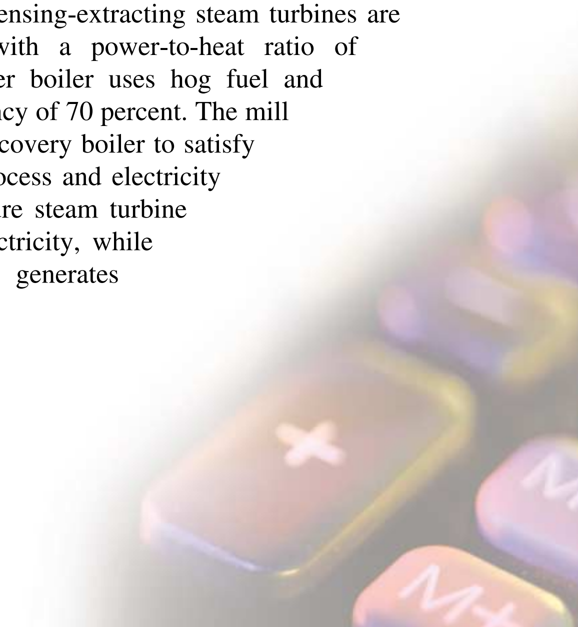
A double-wire press section is used to achieve 50 percent consistence into the dryer section on the machine. This equipment has reduced steam use to 2.3 GJ/ADt at one mill [3]. Electricity consumption was reported at 141 kWh/ADt [3].

## Black Liquor Evaporation

Weak black liquor is produced at 15 percent solids, which is then evaporated to 78 percent solids using a seven-effect multiple-effect evaporation system with an integrated superconcentrator. Steam economy is estimated at 6.0 kg water/kg steam for such an arrangement. The black liquor contains 1.6 kg solids/kg pulp. The steam requirement for the evaporators is calculated to be 3.1 GJ/ADt. The electricity requirement would be 30.0 GJ/ADt [3].

## Power Plant

The mill would use a high solids recovery boiler that achieves a 75 percent heat-to-steam efficiency. Heating value of black liquor would be approximately 6250 Btu/lb. solids (21.0 GJ/ADt pulp). The boiler air is heated to 150ºC using steam, and minimal use of soot blowers is employed, consuming 0.9 GJ/ADt of steam. The mill would recover 70 percent of steam condensate, and the resulting energy use in the deaerator is 1.0 GJ/ ADt. Condensing-extracting steam turbines are used to produce electricity with a power-to-heat ratio of 100 kWh/GJ. The mill's power boiler uses hog fuel and achieves a heat-to-steam efficiency of 70 percent. The mill generates 15.8 GJ/ADt in the recovery boiler to satisfy the heat requirements of the process and electricity generation needs. A backpressure steam turbine generates 520 kWh/ADt of electricity, while excess high-pressure steam generates



another 135 kWh/ADt through a steam-condensing turbine. Therefore, the total electricity generation by the mill is 655 kWh/ADt. The power plant has a parasitic electricity need of about 60 kWh/ADt [3].

### Lime Kiln and Recausticizing

The kiln utilizes flash drying and product coolers to minimize energy consumption. Natural gas is used to provide the 1.2 GJ/ADt of heat energy required. Pressure filters are used for solids separation from process liquors. Electricity requirements will be 50 kWh/ADt [3].

### Hot Water System

Warm water (50ºC) is produced through heat recovery in the evaporator condensers. Hot water (70°C) is produced through heat recovery from the digester surface condenser, cold blow liquor cooling and black liquor cooling. Hot water for use on the pulp machine will be generated using heat recovery from the dryer section. Electricity requirements are 32 kWh/ADt.

### Waste-Water Treatment

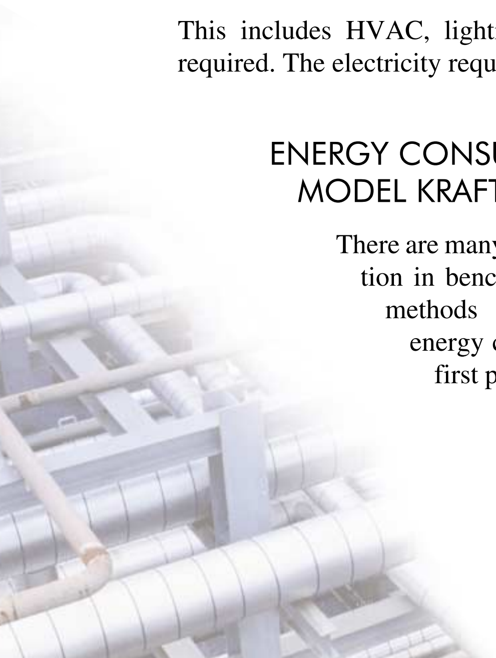
Mill effluent is treated in a primary clarifier and secondary activated sludge basin. Total mill effluent is 35 $m^3$/ADt. A cooling tower is required to remove process heat. Electricity requirements are 30 kWh/ADt for aeration and pumping.

### Miscellaneous

This includes HVAC, lighting, office use, etc. No live steam is required. The electricity requirement is approximately 30 kWh/ADt.

## ENERGY CONSUMPTION IN EXISTING AND MODEL KRAFT MARKET PULP MILLS

There are many ways to compare mill energy consumption in benchmarking studies. We will look at two methods for kraft market pulp mills: process energy consumption and energy purchases. The first provides a measure of the specific energy



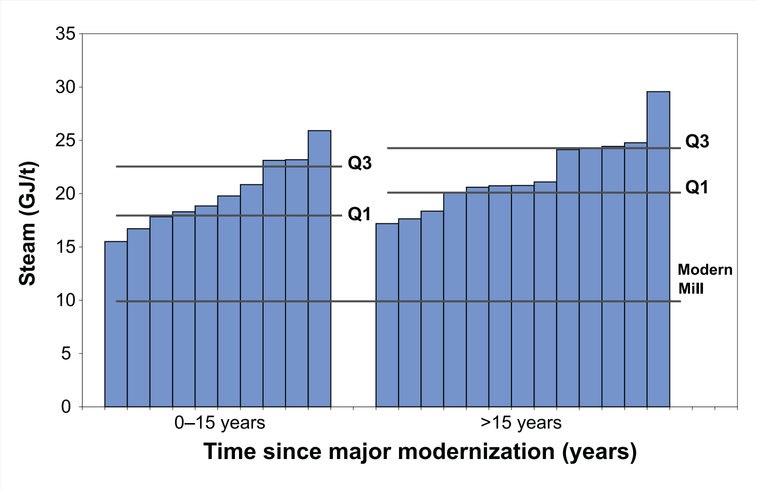


Figure 1. Process steam consumption – kraft mills

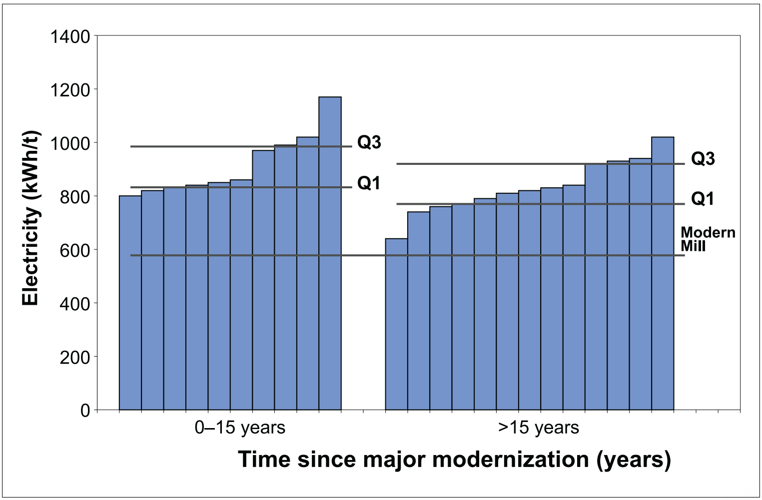


Figure 2. Process electricity consumption – kraft mills

used in pulp and paper manufacturing. The second is influenced by this process energy consumption and also by how that energy is supplied to the

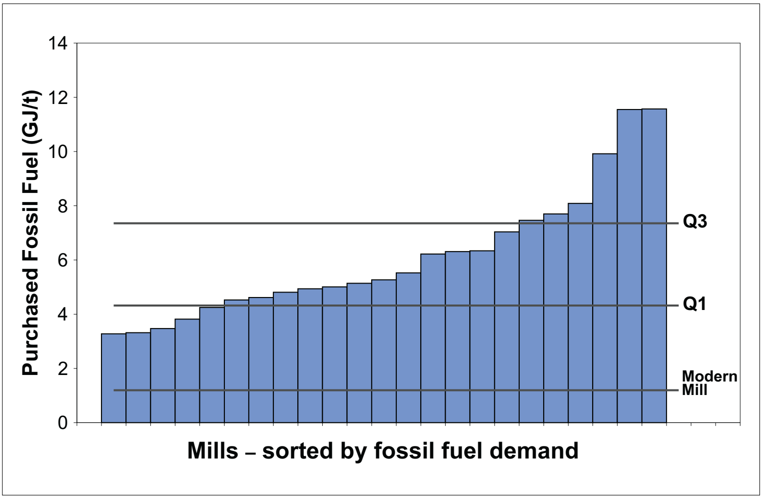


Figure 3. Purchased fossil fuel demand – kraft mills

manufacturing operations. It provides a measure of the costs for energy, both economic and environmental.

The process steam and electricity consumptions for Canadian kraft market pulp mills are shown in Figures 1 and 2. The steam and electricity consumptions were calculated from data in the *CPPA Energy Monitoring Report* for 1999 [2]. The kraft mills are grouped according to the time since their last major modernization. Also shown are the steam and electricity requirements for the model kraft mill.

The data in Figures 1 and 2 show that both older and modernized mills have greater energy consumption than the modern mill. Also, there is little difference in the energy consumption for older and modernized kraft mills. The first and third quartile steam consumption for older mills is only slightly higher than that for modernized mills; the electricity consumption for older mills is slightly lower than that for modernized mills. Some of the older

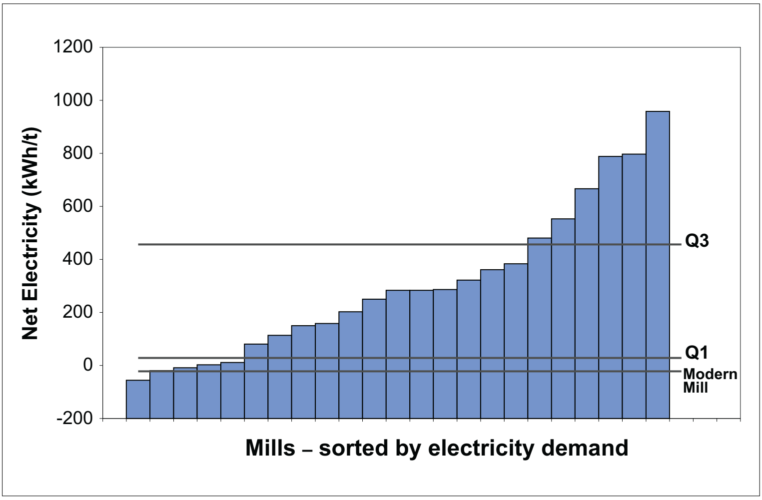


Figure 4. Net electricity demand – kraft mills

facilities are among the lowest overall consumers of process steam and electricity. Thus, new and modernized mills are not achieving the optimum energy consumption levels possible for a modern mill.

The fossil fuel and electricity purchases for kraft mills are shown in Figures 3 and 4. The energy purchases are generally higher than those for the modern mill for two reasons. First, the specific energy used in pulp and paper manufacturing is higher than for the modern mill. Second, how that energy is provided influences the amount of energy purchased. The lower amount of process steam required by the modern mill enables excess steam to be used in a steam-condensing turbine to generate more electricity than a conventional process.

The modern mill uses fossil fuel primarily for the operation of the lime kiln, 1.20 GJ/ADt. Some fossil fuel would also be required for startup of the recovery boiler after a shutdown, but this amount would be very small. The mill would also have a fossil fuel powered

package boiler to provide steam as required during periods of major upset or transition. The average Canadian kraft mill purchased 5.99 GJ/ADt of fossil fuel in 1999, consisting of 4.24 GJ/ADt of natural gas and 1.75 GJ/ADt of fuel oil and other fossil fuels. Assuming a cost of $3.40/GJ for natural gas and $4.03/GJ for fuel oil, the modern mill has $17.39/ADt lower fossil fuel costs than the average Canadian mill.

The modern mill produces all its electricity requirements by steam-condensing and backpressure turbines, with a slight excess of 17 kWh/ADt. There is a large variation in the electricity purchases in Figure 4, resulting from large variations in the amount of power generated by mills. The average electricity purchase was 272 kWh/ADt. Assuming a cost of $0.04/kWh for electricity, the modern mill has $11.56/ADt lower electricity costs than the average Canadian mill.

Thus, there is considerable potential for operating cost savings by optimizing energy usage in kraft market pulp mills. Possible savings for an individual mill can be quickly estimated. First, select a benchmark target; we recommend selecting a target from Figures 1 and 2 midway between the first quartile and modern mill optimum performance for both process steam and electricity. Subtract these figures from the current consumption levels and multiply by the incremental energy costs. This quick reference can help mills to assign priority to energy objectives.

## THE MODEL NEWSPRINT MILL

The model newsprint mill consists of a pulp mill and paper machine along with an effluent treatment facility. The fibre furnish for a modern newsprint mill would consist of thermomechanical pulp (TMP) and/or recycled fibre depending on the fibre availability and market requirements. The energy requirements for pulping and paper making operations are described in the following sections.

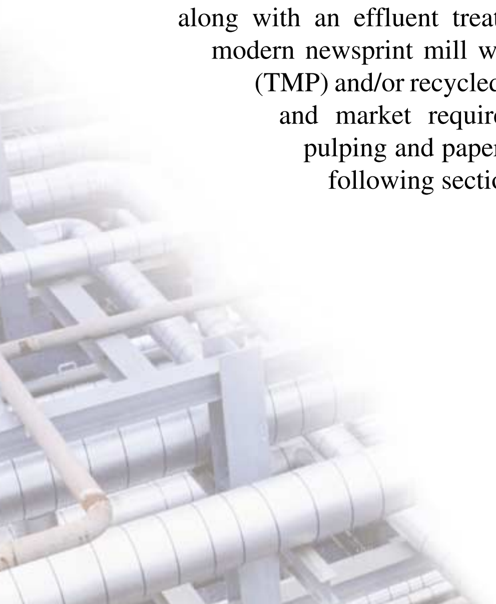


**Table IV. TMP Mill – Steam and Electricity Consumption**

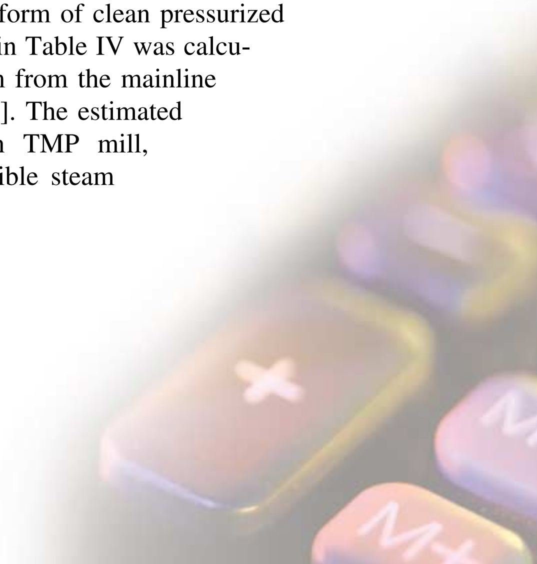
| | *Steam* *GJ/ADt* | *Electricity* *kWh/ADt* |
|---|---|---|
| Chip handling | | 40 |
| Refiners | | 2160 |
| Pumps, screens, agitators, blowers | | 240 |
| Heat recovery | -5.5 | 10 |
| **Total Consumption** | **-5.5** | **2450** |

## *Thermomechanical Pulp Mill*

The energy consumption of a modern TMP mill is shown in Table IV. The mill produces TMP for newsprint manufacture from softwood chips. Jackson and Wild estimated the energy consumption for a 500 BDMT/D single-line TMP mill [5]. The total specific refining energy was 2400 kWh/BDMT, which is typical for TMP from black spruce chips for newsprint production [5]. For comparison, reference may be made to a detailed industrial audit complied by Nygaard [6] for Swedish TMP mills, mostly producing for newsprint. Average external power demand for these mills was similar, about 2420 kWh/ADt.

TMP refining energy is affected by wood species; common Canadian species such as pine require more energy than black spruce [7]. Refining energy is also sensitive to paper grade, with higher-quality mechanical printing paper grades requiring higher energy. Though there are new processes for reducing refining energy somewhat [8], consistent industrial performance has not yet been achieved.

Heat recovery is used in modern TMP newsprint mills to recover some of the refining energy in the form of clean pressurized steam. The clean steam production in Table IV was calculated for heat recovery of the steam from the mainline and rejects refiners by a reboiler [5]. The estimated steam production for the modern TMP mill, 5.5 GJ/ADt, is similar to the possible steam



production calculated by Nygaard, 5.2 GJ/ADt, for the same specific refining energy [6]. The average excess steam production for Swedish TMP mills in 1994 was lower, about 4.4 GJ/ADt [6].

## *Recycled Fibre Mill*

The electricity consumption of a modern recycled fibre mill producing de-inked pulp (DIP) for newsprint manufacture is 400 kWh/ADt [3]. The average external power demand for Swedish recycled fibre mills in 1994 was lower, about 330 kWh/ADt [6]. The steam consumption of a modern recycled fibre mill is 0.8 GJ/ADt, taken from the model recycled fibre mill in Nygaard [6]. The average fuel heat demand for Swedish recycled fibre mills in 1994 was lower, about 0.3 GJ/ADt [6].

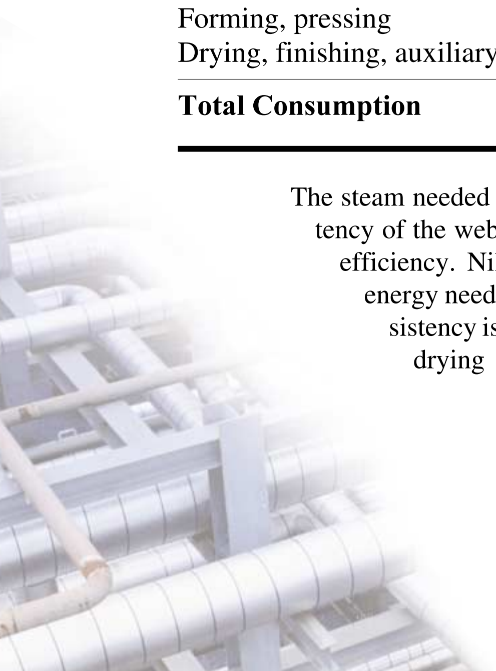
## *Paper Machine*

The energy consumption for a modern newsprint paper machine is shown in Table V [9]. The average electricity consumption for Swedish newsprint paper mills in 1994 was higher, about 440 kWh/ADt [6]. Talja et al. measured 344 kWh/ADt electricity consumption for a modern paper machine producing SC paper [10].

**Table V. Newsprint Paper Machine – Steam and Electricity Consumption**

| | *Steam GJ/ADt* | *Electricity kWh/ADt* |
|---|---|---|
| Stock preparation | 0.7 | 100 |
| Forming, pressing | 0.3 | 140 |
| Drying, finishing, auxiliary systems | 3.4 | 90 |
| **Total Consumption** | **4.4** | **330** |

The steam needed for paper drying depends on the consistency of the web after the press section and the machine efficiency. Nilsson et al. reported that the minimum energy needed for drying from 50 to 90 percent consistency is 2.26 GJ/ADt of paper produced [3]. The drying steam consumption of 3.4 GJ/ADt is



equivalent to the steam needed to dry the web from 43 percent consistency, assuming 1.25 kg steam per kg of water evaporated [11] and 10 percent paper machine losses due to trim and machine breaks. Talja et al. measured 2.71 GJ/ADt total steam consumption for a modern paper machine producing SC paper [10].

## Effluent Treatment

The effluent treatment consists of primary clarification and activated sludge treatment. The electricity consumption for effluent treatment is 60 kWh/ADt [5].

## Integrated Newsprint Mill

The energy consumption for three modern integrated newsprint mills is shown in Table VI. The pulp furnish for the three mills are TMP, DIP and 80 percent TMP+20 percent DIP. The recycled fibre content of the TMP/DIP newsprint mill was chosen to match the average recycled content of newsprint mills in the *CPPA Energy Monitoring Report* [2].

The differences in steam and electricity consumption among the three mills are related to the energy needed for pulping and heat recovery. DIP production requires less energy than TMP production but does not produce steam that can be recovered and re-used in the paper machine. The potential clean steam production by heat recovery in the TMP newsprint mill is greater than the paper machine steam requirement, giving a net steam production of 1.1 GJ/ADt.

The energy consumption for the TMP newsprint and DIP newsprint mills in Table VI is similar to that reported by Lähepelto, based on a study made by Jaakko Pöyry [12]. The energy consumption reported for a modern TMP newsprint mill was -1.33 GJ/ADt heat and 2190 kWh/ADt electricity [12]. The difference in electricity consumption is due to different specific energies for TMP refining. The energy consumption reported for a modern DIP newsprint mill was 5.27 GJ/ADt heat and 870 kWh/ADt electricity [12].

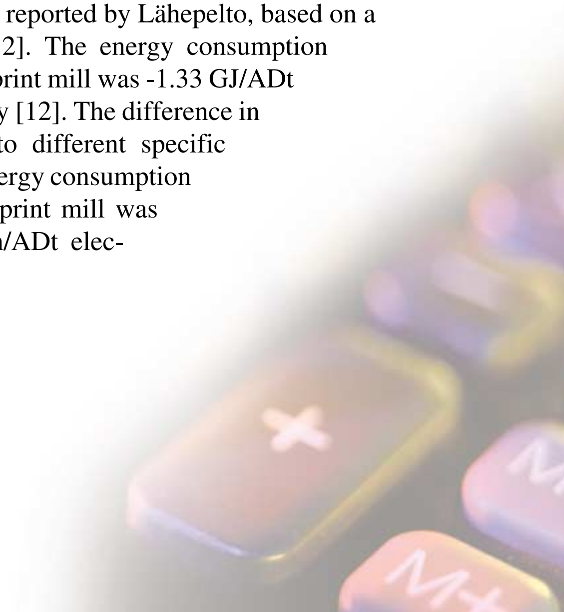


**Table VI. Modern Newsprint Mill – Steam and Electricity Consumption**

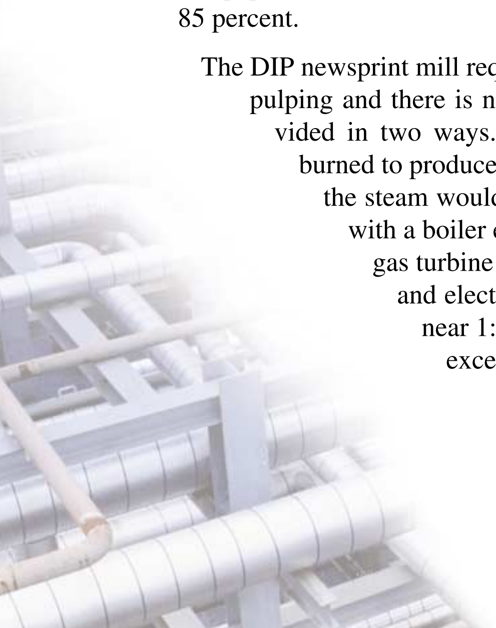
| | *TMP* | | *DIP* | | *80% TMP + 20% DIP* | |
|---|---|---|---|---|---|---|
| | *Steam GJ/ADt* | *Electricity kWh/ADt* | *Steam GJ/ADt* | *Electricity kWh/ADt* | *Steam GJ/ADt* | *Electricity kWh/ADt* |
| TMP | -5.5 | 2450 | | | -4.4 | 1960 |
| DIP | | | 0.8 | 400 | 0.2 | 80 |
| Paper machine | 4.4 | 330 | 4.4 | 330 | 4.4 | 330 |
| Effluent treatment | | 60 | | 60 | | 60 |
| **Total Consumption** | **-1.1** | **2840** | **5.2** | **790** | **0.2** | **2430** |

**Table VII. Modern Newsprint Mill – Energy Consumption**

| | *TMP* | *DIP* | *80% TMP + 20% DIP* |
|---|---|---|---|
| Electricity, kWh/ADt | 2840.0 | 790.0 | 2430.0 |
| Fossil fuel, GJ/ADt | 0.5 | 6.1 | 0.8 |

The purchased energy consumption for the three modern integrated newsprint mills is shown in Table VII. For the TMP newsprint mill, no steam needs to be generated by burning fossil fuels during normal TMP mill operation due to the excess steam produced by heat recovery. However, a backup steam system including a package boiler and steam accumulator is needed to provide process steam during upset conditions [5]. It was assumed in Table VII that a natural gas fired boiler would provide backup steam equivalent to 10 percent of the paper machine steam consumption with a boiler efficiency of 85 percent.

The DIP newsprint mill requires steam since less energy is used for pulping and there is no heat recovery. The steam can be provided in two ways. First, fossil fuel and sludge could be burned to produce steam. It was assumed in Table VII that the steam would be provided by natural gas fired boiler with a boiler efficiency of 85 percent. Alternatively, a gas turbine cogeneration plant could produce steam and electricity. Assuming a power-to-steam ratio near 1:1, the cogeneration plant would produce excess electricity that could be sold [13].



The TMP/DIP newsprint mill supplies most of its steam requirement by heat recovery under normal operating conditions. However, a backup steam system is also needed to provide process steam during upset conditions in the TMP mill. It was assumed in Table VII that a natural gas fired boiler would provide 0.2 GJ/ADt continuous steam and backup steam equivalent to 10 percent of the paper machine steam consumption with a boiler efficiency of 85 percent.

The modern newsprint mill was assumed to have heat recovery of mainline and reject refiners. Some mills may choose not to recover reject refiner steam, increasing the steam demand from the power boiler. This steam demand would be met by burning hog fuel and sludge. In 1999, Canadian newsprint mills produced 3.97 GJ/ADt of steam from hog fuel and sludge [2]. Thus, this lower heat recovery would not necessarily increase the fossil fuel consumption and the resulting GHG emissions.

## ENERGY CONSUMPTION IN EXISTING AND MODEL NEWSPRINT MILLS

The process steam and electricity consumptions for newsprint mills are shown in Figures 5 and 6. The steam and electricity consumptions were calculated from data in the *CPPA Energy Monitoring Report* for 1999 [2]. The mills in the CPPA survey used TMP and/or recycled fibre, with an average recycled fibre content of about 20 percent.

In Figure 5, the process steam consumption varied from 2.52 to 12.69 GJ/t, greater than the steam demand of 0.64 GJ/t for the modern newsprint mill. This large variation results from differences in the amount of steam used in the process and differences in heat recovery of refiner steam. Recycled fibre content also affects the steam consumption, since no refiner steam is available for heat recovery in a recycled fibre mill.

The fossil fuel purchases for newsprint mills are shown in Figure 7. The fossil fuel purchases are generally higher than those for the modern mill due to greater steam usage in the process and lower heat recovery. Some mills use large amounts of hog fuel for steam generation, reducing fossil fuel purchases.

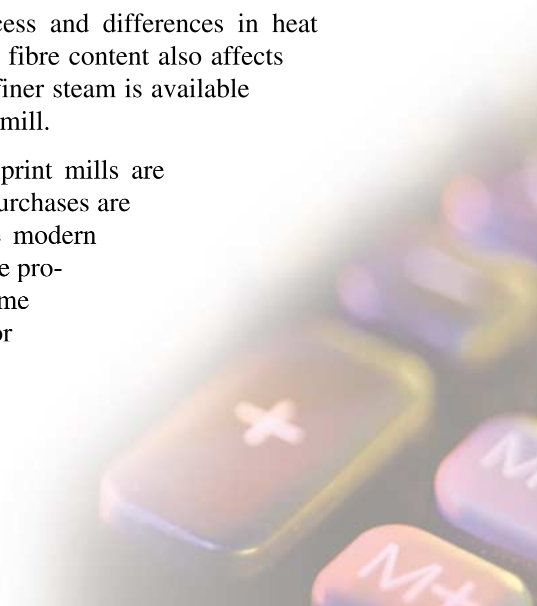


Figure 5. Process steam consumption – newsprint mills

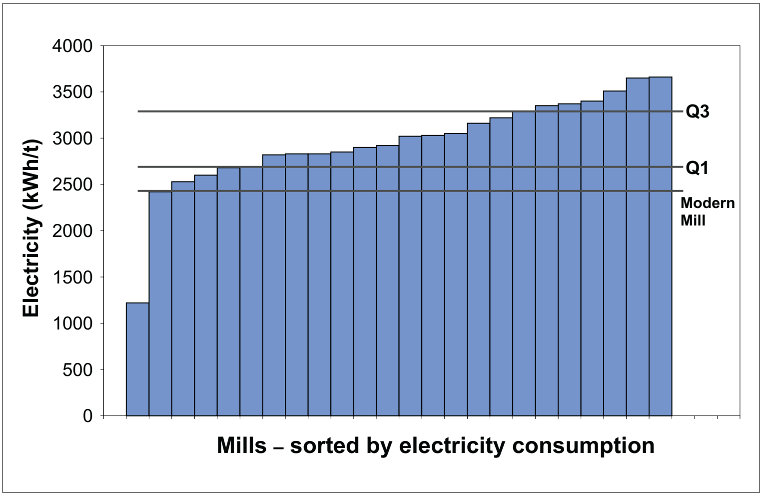
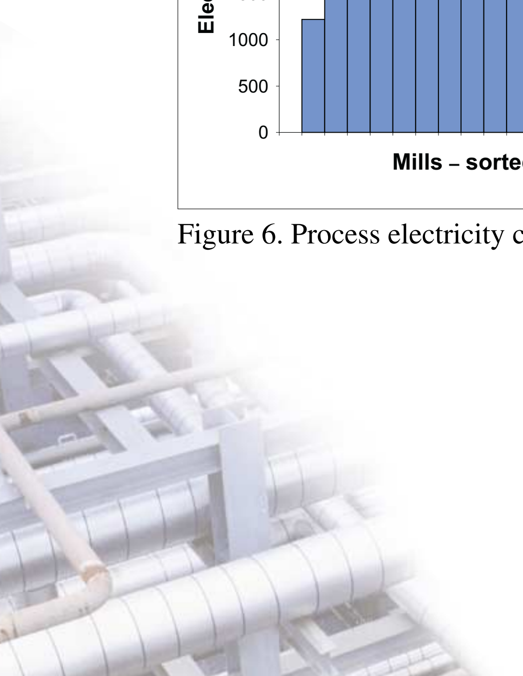


Figure 6. Process electricity consumption – newsprint mills



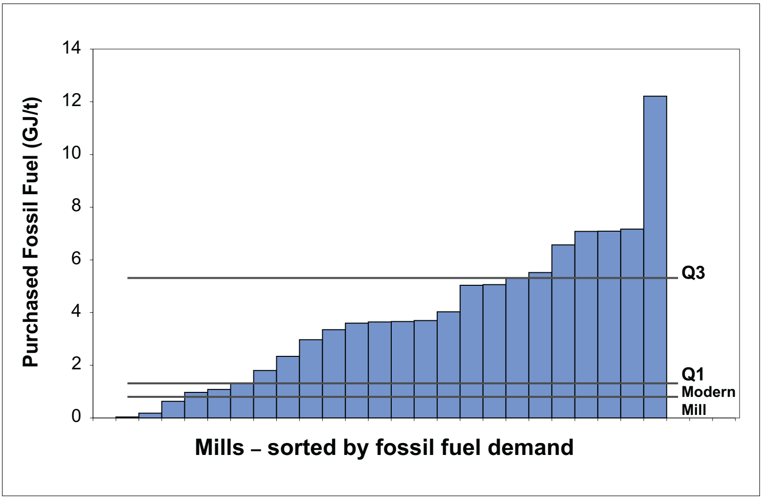


Figure 7. Purchased fossil fuel demand – newsprint mills

The modern mill provides most of its steam requirement by heat recovery under normal operating conditions. Fossil fuel, 0.80 GJ/t, is needed only to provide backup steam during upset conditions. The average newsprint mill purchased 3.56 GJ/t of fossil fuel in 1999, consisting of 1.80 GJ/t of natural gas and 1.73 GJ/t of fuel oil and other fossil fuels. It also purchased 0.90 GJ/t of steam. The modern mill has $16.69/ADt lower thermal energy (fossil fuel and steam) costs than the average Canadian mill, assuming that the purchased steam was produced with natural gas.

The process electricity consumption, shown in Figure 6, ranged from 1220 to 3660 kWh/ADt. The variation in electricity consumption is due in part to variations in recycled fibre content and TMP refining energy. The average electricity consumption was 2850 kWh/ADt. Most mills used more electricity than predicted for the modern TMP/DIP newsprint mill, 2430 kWh/ADt. However, most of the electricity used in a TMP/DIP newsprint mill is used for TMP refining. Thus, much of the higher energy input is likely attributable to the wood species employed and the grade of paper produced. Changes in pumping and agitation throughout the mill may result in a 5 percent overall drop in electricity consumption, or a potential savings of about $5.70/ADt.

Thus, there is also considerable potential for operating cost savings by optimizing energy usage in newsprint mills. Possible savings in fossil fuels for an individual mill can be estimated in the same way as for kraft mills. Possible savings in electricity are more difficult to estimate, since the large electricity use for refining is governed by product quality requirements.

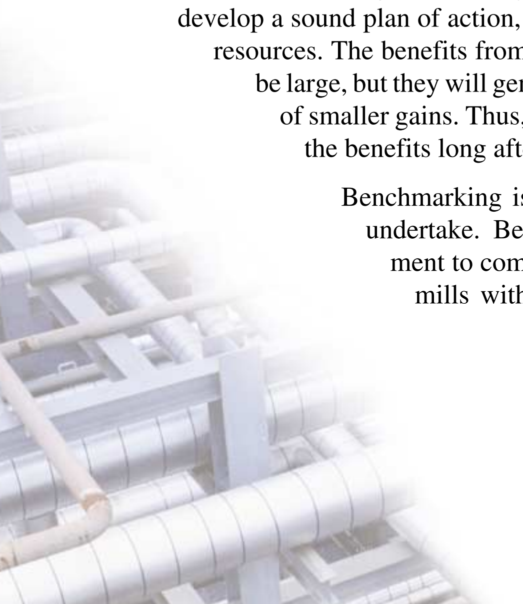
## ENERGY COST REDUCTION IN EXISTING MILLS

Converting an existing mill to the specifications of the model mill will frequently be capital intensive and may not be economically feasible when energy costs are the only advantage. However, there is considerable potential for cost-effective energy use reduction in existing pulp and paper mills [14, 16]. Reference [14] contains a detailed examination of best energy practices and provides a set of tools for planning a systematic approach towards achieving these best practices in existing pulp and paper mills. Reference [14], which serves as the basis for a short course in energy efficiency presented by the Pulp and Paper Technical Association of Canada (PAPTAC), is summarized in [15] and outlined next.

### *Management Overview*

The implementation of an energy conservation program frequently requires a change in the culture of a mill. Cultural changes must start with senior management. They must be committed to the process, develop a sound plan of action, provide the leadership and secure the resources. The benefits from an energy conservation program can be large, but they will generally be derived from a large number of smaller gains. Thus, continuous effort is required to retain the benefits long after the projects are implemented.

Benchmarking is one of the first steps a mill should undertake. Benchmarking enables senior management to compare the relative performance of their mills with similar mills or with a model mill



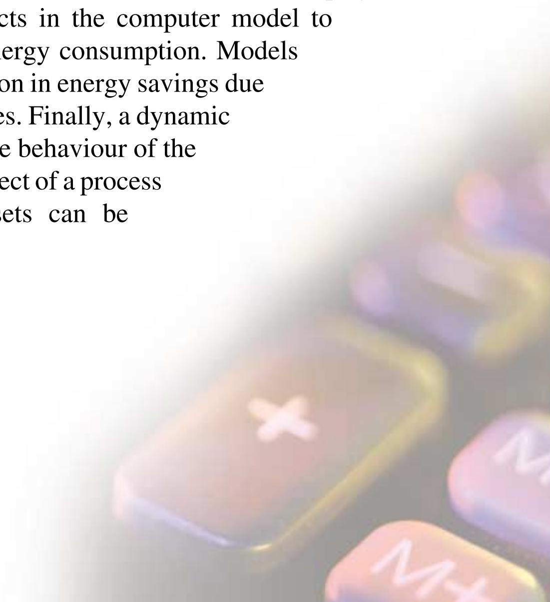
representing the current best practice. It provides the motivation for looking at energy conservation opportunities in mill operations.

Next, an energy efficiency program must be put in place. The program should be led by a mill engineer with sufficient resources allocated for the task, assisted by a team of mill staff, outside consultants and other experts drawn from all areas of mill operations. As described in [1], this cross-functional team will attend to the details of implementing the program.

## *Process Analysis and Energy Optimization*

Existing mills frequently consist of several pulping and papermaking production lines, installed at 10- or 20-year intervals since construction of the original mill. In many cases the original equipment will have been removed, but auxiliary equipment such as steam or water supply systems will still be in place. There will also have been new effluent systems and, perhaps, new boilers or cogeneration plants installed at various intervals. At the time of installation, each new system was integrated with the existing systems to a greater or lesser degree, leading in many cases to a large degree of interdependency between old and new systems. In such a complex process, it is difficult to ensure that energy savings in one part of the operation do not lead to losses elsewhere. A systems engineering approach is essential to ensure that any energy efficiency project reduces the global energy use of the mill, and doesn’t merely shift the energy use to another department or mill area.

The simplest process analysis tool is a computer simulation of the mill-wide mass and energy balance. This allows mill staff to play “what if,” by implementing projects in the computer model to check the effect on overall mill energy consumption. Models can also predict the seasonal variation in energy savings due to changing fresh water temperatures. Finally, a dynamic simulation allows the unsteady-state behaviour of the system to be analysed so that the effect of a process change on behaviour during upsets can be evaluated.



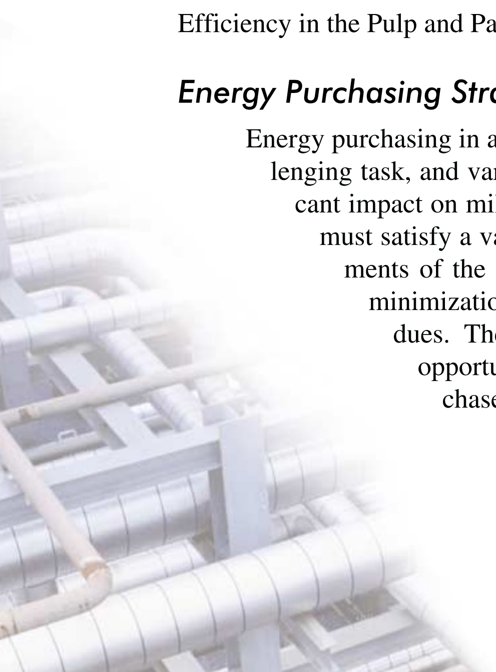
However, playing "what if" can be time-consuming and does not necessarily lead to the best or most effective solution. Process integration tools, such as pinch analysis, identify the minimum theoretical energy consumption level of a process and provide guidelines for the modifications required to reach that minimum level. Pinch analysis is a powerful tool, which must nonetheless be applied with care, as there may be good process reasons why a particular heat recovery project cannot be implemented. As well, the minimum energy consumption levels may require large capital expenditures, and not all heat recovery projects will be economically feasible at a given price for energy. Nonetheless, awareness of the theoretical minimum energy consumption level is a powerful motivator for improving efficiency and reducing waste.

## *Processes and Process Equipment*

Each process area in a mill should be compared with the industry average, and with the model mill, to see how it compares with best practices and where it can be improved. Reference [14] provides guidance on energy use in chemical, mechanical and de-inked pulp mills, in papermaking and in non-process areas such as steam plants, boiler rooms, cogeneration installations and effluent treatment systems. Guidance is also provided on selecting and controlling pump and fans in a cost- and energy-effective manner. Additionally, references [16, 17] provide examples of projects implemented in mills, with estimates of capital costs and operating cost savings. Finally, each mill area is discussed in detail in the PAPTAC short course, "Improving Energy Efficiency in the Pulp and Paper Industry."

## *Energy Purchasing Strategies*

Energy purchasing in a deregulated environment can be a challenging task, and variable energy pricing can have a significant impact on mill operations. Energy sourcing decisions must satisfy a variety of objectives: operational requirements of the mill, cost minimization, $CO_2$ emissions minimization and disposal of sawmill and other residues. The restructured energy markets provide opportunities to achieve cost savings in purchased energy if mills can be flexible in their



energy use patterns. Considerable changes in operating culture may be required to exploit these opportunities, beginning with more active management of energy demands and increased integration of management and energy purchasing functions. Financial risk management tools will become more important as energy markets are deregulated.

## *Project Identification and Selection*

Ranking and selecting projects is a standard task for mill engineering staff and involves calculating estimated payback, return on investment or some other standard corporate economic indicator. However, there are a number of additional concerns when ranking energy efficiency projects.

For instance, the order in which a series of projects is implemented can have an impact on the total return. As an example, any project where heat is transferred to boiler makeup water will not result in continuous savings if, at a later date, other projects, such as reduced steam consumption or improved condensate return, reduce the flow of makeup water. It is important to be aware of these cross-effects at an early stage in the project selection process.

As well, there may be economic advantages to reducing $CO_2$ emissions. Emissions trading is still in its infancy but could yield substantial revenues as programs to limit GHG emissions become more widely recognized by legislative and regulatory agencies. The economic benefits arising from reducing energy consumption may exceed the energy cost savings, and could include a credit for every tonne of $CO_2$ emissions reduction achieved by either reducing fossil fuel consumption or switching from a dirty fuel to a cleaner one.

Finally, opportunities for reducing energy when planning production increases or improvements in product quality should also be considered. Frequently a small additional capital expense for more efficient equipment or processing methods can lead to better payback periods than if the energy project were considered by itself at a later date.

These and other novel project ranking methods should be part of every energy efficiency program.

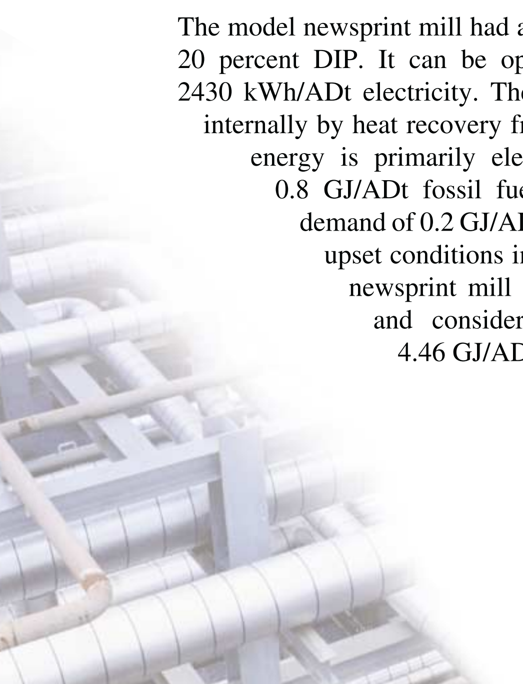
### *Continuous Performance Monitoring and Improvement*

Once capital budgets have been allocated and the projects implemented, it is important to be able to show that the savings continue to be reaped, year after year. As well, it is important to treat energy efficiency as a continuous improvement process: once a set of projects has been implemented, it is important to start planning the next iteration in the energy efficiency program. For these reasons, a continuous monitoring and improvement system must be put in place. A mix of hardware, software and management practices, these systems ensure that once a steam line is shut, it remains shut, that once a process has been adjusted, it remains adjusted, and that the economic benefits continue to accumulate.

## CONCLUSION

There is considerable potential for energy use reduction in pulp and paper mills. The model kraft mill can be operated with 9.9 GJ/ADt process steam, 1.2 GJ/ADt process fossil fuel and 578 kWh/ADt process electricity. The process steam and electricity demands can be met by burning the spent pulping liquor and the hog fuel associated with the chip supply. Thus, the only purchased energy is the 1.2 GJ/ADt of fossil fuel needed for the lime kiln. The average existing kraft mill, however, purchases considerably more energy: 5.99 GJ/ADt of fossil fuel and 272 kWh/ADt of electricity.

The model newsprint mill had a fibre furnish of 80 percent TMP and 20 percent DIP. It can be operated with 0.2 GJ/ADt steam and 2430 kWh/ADt electricity. The main steam demands are provided internally by heat recovery from the refiner steam. The purchased energy is primarily electricity, 2430 kWh/ADt, with only 0.8 GJ/ADt fossil fuel needed for the continuous steam demand of 0.2 GJ/ADt and to provide backup steam during upset conditions in the TMP mill. The average existing newsprint mill purchases 2850 kWh/ADt electricity and considerably more steam and fossil fuel, 4.46 GJ/ADt.



Existing mills can approach the lower energy demand of the model mills through an energy efficiency program. The monograph *Energy Cost Reduction in the Pulp and Paper Industry* contains a detailed examination of best energy practices and provides a set of tools for planning a systematic approach towards achieving these best practices in existing pulp and paper mills [14]. It serves as the basis for a short course in energy efficiency offered by PAPTAC.

## REFERENCES

1. Connaghan, C. and Wunderlich, R., “Developing, Implementing and Maintaining an Energy Efficiency Program,” Energy Cost Reduction in the Pulp and Paper Industry, Browne, T.C. tech. ed., Paprican (1999).
2. Energy Monitoring Report, Year ended 31 December 1999, CPPA.
3. Nilsson, L.J., Larson, E.D., Gilbreath, K.R. and Gupta, A., “Energy Efficiency and the Pulp and Paper Industry,” American Council for an Energy-Efficient Economy, Berkeley, CA (1995).
4. Bechberger, E.J., “Reduction of Salt Cake and Production of Caustic from a Chlorine Dioxide Generator,” Preprints of the 1992 CPPA Spring Conference, Jasper, Alberta (1992).
5. Jackson, M. and Wild, N. “Mechanical Pulp Mills,” Energy Cost Reduction in the Pulp and Paper Industry, Browne, T.C. tech. ed., Paprican (1999).
6. Nygaard, J., Energy aspects on mechanical pulp, chemical pulp and recycled fibres. International Mechanical Pulping Conference:17-27 (1997).
7. Laliberté, D., Shallhorn, P.M. and Karnis, A., Comparison of TMP and CTMP Properties from Spruce and Pine Sawmill Chips. Pulp Paper Can. 88(3):T71-T100 (1987).
8. Corson, S., Mechanics of Making Better Pulp with Less Energy. Pulp Pap. Int. 39(5):61-65 (1997).
9. AF Publication (in Swedish), Models for energy conservation in pulp and paper manufacturing. Stockholm, 1978.
10. Talja, R., Kerttula, R. and Karlsson, M., Future paper production line concepts regarding energy and environmental aspects. Das Papier 51(6A):V203-V207 (1997).
11. Persson, B., Drying section: The least developed part of the paper machine. Nordisk Cellulosa 5(5):75-77 (1988).

12. Lähepelto, J., Rational use of energy in the Finnish paper industry – The sustainable paper energy research programme. Das Papier 51(6A):V200-V203 (1997).
13. Karojärvi, R., Liimatainen, H. and Tapio, M., Impact of advanced co-generation methods on energy demand in mechanical pulping. First EcoPaperTech, an International Conference on Papermaking and Paper-Machine Technology: 303-314 (1995).
14. Energy Cost Reduction in the Pulp and Paper Industry, Browne, T.C. tech. ed., Paprican (1999).
15. Browne, T.C., Francis, D.W. and Towers, M.T., Energy cost reduction in the pulp and paper industry: an overview. Pulp Paper Can. 102(2):T34-T38 (2001).
16. A Guide to Energy Savings Opportunities in the Kraft Pulp Industry. PAPTAC (2000).
17. Energy Conservation Opportunities, 4 volumes, PAPTAC (1992, 1993, 1994, 2001).