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BENCHMARKING ENERGY USE IN

CANADIAN PULP AND PAPER MILLS

IN COLLABORATION WITH THE PULP AND PAPER RESEARCH INSTITUTE OF CANADA

CIPEC

Canada

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TABLE OF CONTENTS

List of Figures

List of Tables

FOREWORD

The Canadian pulp and paper sector, founded 200 years ago, has become an important component of the Canadian economy. Pulp and paper manufacturing is highly integrated with its allied sectors in the forest products industry—forestry and wood products.

The forest products industry contributes 3 percent of Canada's gross domestic product. The industry operates in communities throughout Canada, providing direct employment for 360 000 Canadians.

The pulp and paper sector is one of the most energy-intensive sectors, consuming approximately 30 percent of the industrial energy used in Canada. Because energy is a significant production-cost component (about 25 percent), the sector has made efforts to reduce its fuel costs by switching to renewable biomass sources (by-products of the production process) and energy efficiency improvements.

Pulp and paper manufacturing is unique among manufacturing sectors in that it sources 57 percent of its energy consumption from biomass. As well, the sector reduced its energy use by an average of 1 percent annually since 1990 through improvements in energy efficiency. These achievements have been well documented by the industry and through initiatives such as the Canadian Industry Program for Energy Conservation (CIPEC).

Although its progress on energy conservation is impressive, the pulp and paper sector wants and needs to go further. The sector aims to produce all the energy it requires, to ensure its long-term competitiveness in the global market. In fact, the industry has the potential to become a net exporter of energy. It has the largest industrial cogeneration capacity in Canada and has the potential for further installations.

How can the industry become more energy efficient? It must implement both proven and new technology. However, mills must understand how they use energy before they adopt new energy sources or technology.

That is where energy benchmarking can help. This benchmarking study, conducted by the Pulp and Paper Research Institute of Canada (Paprican), shows how the sector uses energy. The study found causes of wasted energy, but also revealed that sector best practices are near the theoretical minimums for certain process segments.

Its results will help Canada's pulp and paper manufacturers adopt today's best practices more consistently across the sector while investigating the best practices of tomorrow.

1

INTRODUCTION

4

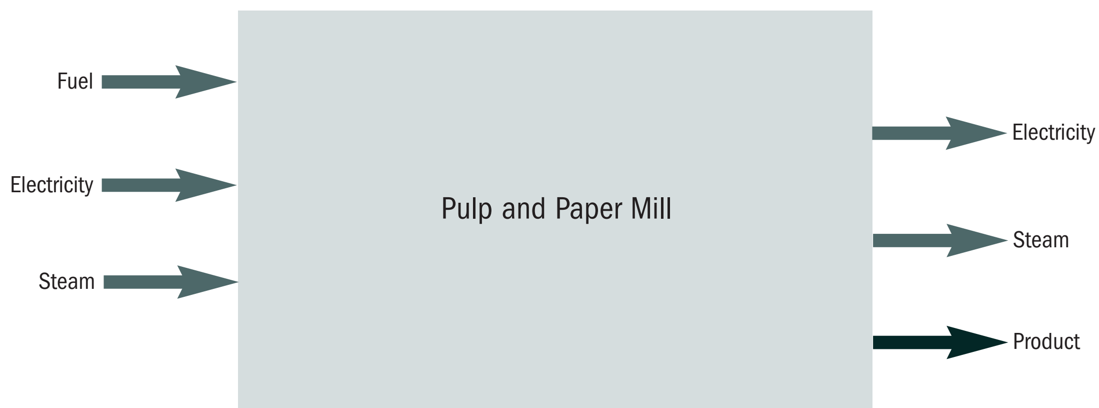
1. INTRODUCTION

A benchmarking study compares the performance of a mill with its competitors or with a model mill that has new technology.

The results can be a valuable motivating force for change, both in operating practice and capital investment. A mill can assess its operating costs (energy) and environmental impact (greenhouse gas emissions) relative to its competitors and relative to the lowest values that can be obtained practically.

Governments and pulp and paper trade associations, such as the Forest Products Association of Canada (FPAC), collect data about energy use and about pulp and paper production for economic policy and planning. See Figure 1-1.

Figure 1-1 Energy inputs and outputs of a pulp and paper mill



These groups collect data on
- purchased energy (electricity, steam, fossil fuels)
- self-generated energy (hog fuel, sludge, spent pulping liquor, hydroelectric power)
- sold energy (electricity, steam)
- pulp and paper production

These data can be used to calculate the energy intensity of a mill, by dividing the mill's energy consumption by its pulp and paper production.

The energy intensity can be used for global benchmarking even when you do not know specifics about the products and manufacturing processes.[1] Global benchmarking makes an initial assessment of where the mill's operations rank in the industry. However, this benchmarking can identify only the potential for energy savings, not where they can be achieved.

[1] Connaghan, C. and R. Wunderlich. "Developing, Implementing and Maintaining an Energy Efficiency Program" *Energy Cost Reduction in the Pulp and Paper Industry*, Browne, T.C and P.N. Williamson, eds. Pulp and Paper Research Institute of Canada, Montréal, 1999.

To identify where process improvements and energy savings can be achieved, benchmarking comparisons should be made for individual process areas in the mill.

For example, in a thermomechanical pulp (TMP) newsprint mill, the total steam demand is determined by the performance of both the TMP reboiler and the paper machine dryer. High steam consumption can result from poor performance of the reboiler or the dryer, and a global benchmarking survey cannot determine which area requires improvement. However, by comparing these two individual process areas you can determine which area requires improvement.

In this report, the Pulp and Paper Research Institute of Canada (Paprican) describes a method for benchmarking the energy use for process areas in pulp and paper mills. Paprican then presents the results of a benchmarking survey of energy use in Canadian pulp and paper operations.

In “Methodology,” the benchmarking method is explained. Energy use in pulp and paper mills was analysed by examining energy conversion areas and manufacturing areas.

In “Results,” the results of the detailed data analysis in manufacturing areas and energy conversion areas from 49 mills are presented.

In “Discussion,” the energy consumption to produce two product grades, kraft pulp and newsprint, from TMP is determined by combining the relevant manufacturing areas at mill sites.

In “Interpretation of the Results,” reasons are given for why the results for each area benchmarked may differ.

“How do the results affect my mill?” presents information about how to use the results from the benchmarking study.

“What steps do I take?” provides a seven-step process explaining how you can start to find opportunities for energy efficiency improvements.

“Appendix A. Area definitions” lists the definitions for the process areas in the pulp and paper mill.

Sample calculations are described in “Appendix B. Sample calculation.”

“Appendix C. Energy benchmarking survey instructions” concludes the report with instructions on how to benchmark your facility using the enclosed CD-ROM, which includes an Excel workbook. The workbook contains spreadsheets (six visible and one hidden) with step-by-step instructions. The information is not intended to replace the findings of a formal energy benchmarking study at a facility.

2 METHODOLOGY

2. METHODOLOGY

The Pulp and Paper Research Institute of Canada (Paprican) developed a methodology to benchmark the energy use in pulp and paper mills by process area.[2]

This method is based on the approach developed by the International Energy Agency (IEA) Programme on Advanced Energy-Efficient Technologies for the Pulp and Paper Industry for life-cycle studies.[3]

Data are collected on
- purchased energy
- self-generated energy
- sold energy
- pulp and paper production

With this information, you can make global benchmarking comparisons for mill operations. The energy and fibre resources are allocated to areas. This allows benchmarking comparisons for individual areas in a mill and for product grades.

The benchmarking method has four steps:
- establish process areas
- collect data
- allocate and reconcile data
- calculate energy consumption

Establish process areas
The first step is to divide the pulp and paper mill into process areas. The areas are described in Appendix A.

Figure 2-1 shows the process areas of a mill that produce newsprint and kraft market pulp from TMP and kraft pulp.

There are two kinds of process areas: energy conversion areas and pulp and paper manufacturing areas. In the energy conversion areas, purchased and self-generated energy are converted to steam and electricity for use in the manufacturing areas or for sale. The energy conversion areas include power and recovery boilers, a backpressure turbine and a deaerator.

In the manufacturing areas of pulp and paper manufacturing operations, energy resources (fuel, steam and electricity) and fibre resources are used to produce newsprint and kraft market pulp.

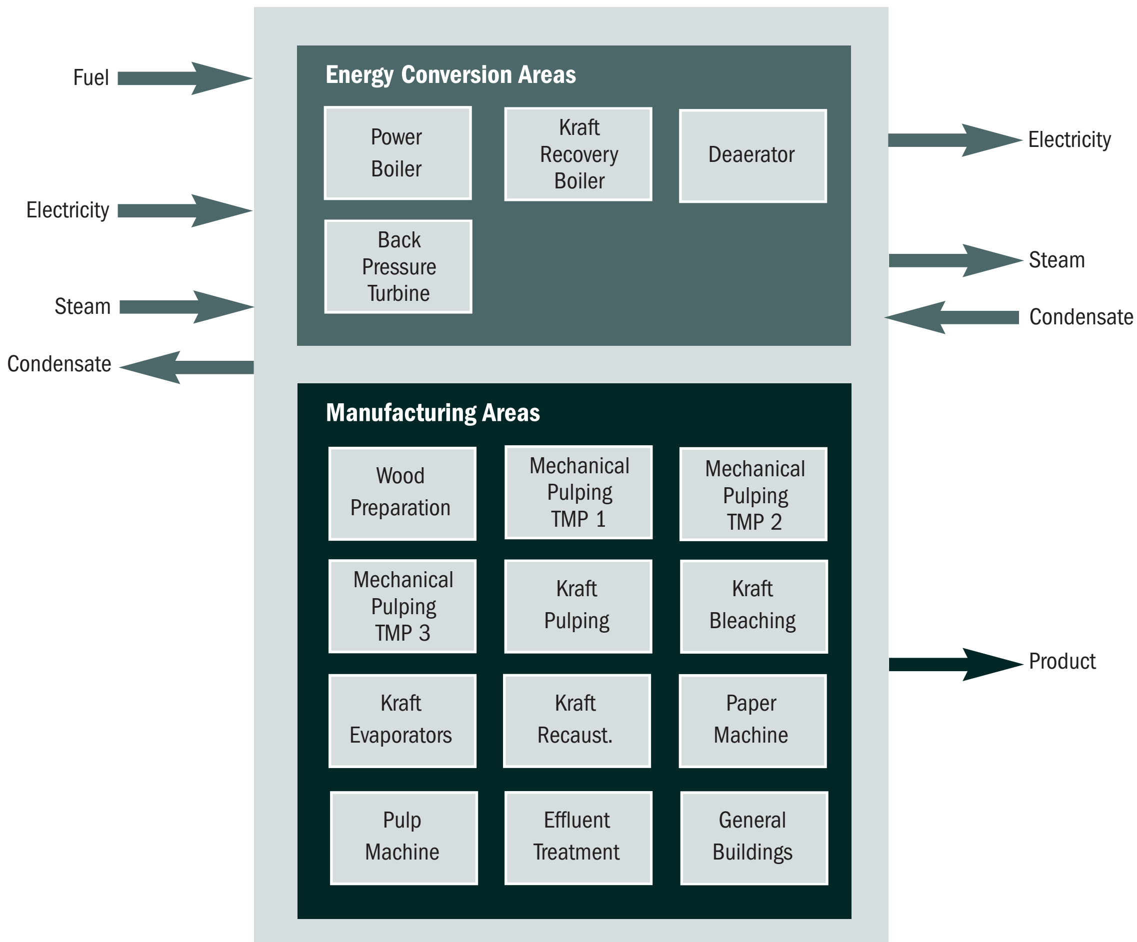
[2] Francis, D.W. *Method for Benchmarking Energy Usage in Pulp and Paper Operations*, PAPTAC Midwest Branch Meeting, Thunder Bay, Ontario, September 25–27, 2002.

[3] IEA Programme on Advanced Energy-Efficient Technologies for the Pulp and Paper Industry. "Recommended Methods for Energy Reporting in Pulp and Paper Industry, Summary Report" *Assessment of Life-Cycle-Wide Energy-Related Environmental Impacts in the Pulp and Paper Industry, IEA*, 1999.

The manufacturing areas include

- wood preparation
- mechanical pulping
- kraft pulping
- bleaching
- evaporators
- recausticizing
- paper and pulp machines
- effluent treatment
- general areas (for example, buildings)

Figure 2-1 Energy conversion areas and manufacturing areas of the pulp and paper mill



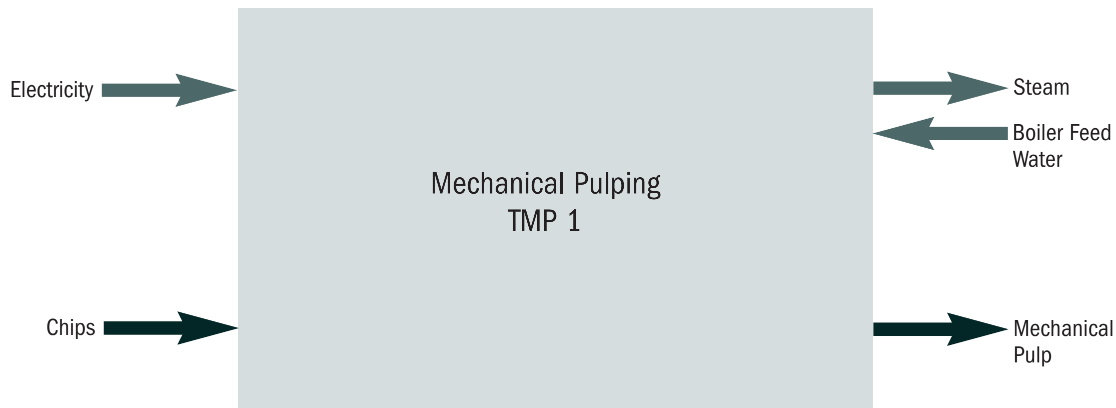
Each of the energy conversion and manufacturing areas is defined by its product.

For example, the mechanical pulping area in Figure 2.2 produces TMP from electricity and chips. The input boundary is the inlet of the chip bin; the output boundary is the pulp storage tank after thickening.

The mechanical pulping area includes
- chip steaming
- refining
- screening
- rejects refining

There is also a reboiler for heat recovery from the refiner steam. Therefore, this mechanical pulping area also produces steam from boiler feed water and electricity.

Figure 2-2 Energy and fibre inputs and outputs for a mechanical pulping area



In Figure 2-2, the energy intensity of the process area is the energy consumption divided by the pulp production. The energy intensity is calculated by using the reconciled data. For each energy conversion and manufacturing area, technology descriptors are defined to account for different energy use by different technologies. For example, in mechanical pulping, the energy use varies relative to the pulping process and the heat recovery.

The pulping process descriptors for mechanical pulping are
- stone groundwood (SGW)
- pressurized groundwood (PGW)
- refiner mechanical pulp (RMP)
- thermomechanical pulp (TMP)
- chemithermomechanical pulp (CTMP)
- thermopulp or RTS
- other (specify)

The heat recovery descriptors are
- primary refiners only
- mainline refiners only
- mainline and reject refiners
- none

These technology descriptors allow you to make benchmarking comparisons among areas with the same technology (for example, TMP lines) or between areas with different technologies (for example, between SGW lines and TMP lines). Similar technology descriptors are defined for the other energy conversion and manufacturing areas. See Appendix A.

Collect data
The second step is to collect data on energy inputs and outputs for the mill and for pulp and paper production. This is the same information that is collected in global benchmarking studies.

For the mill in Figure 2-1, the energy inputs can include fuel (purchased fossil fuel, self-generated spent pulping liquor), electricity and steam. The energy outputs can include electricity and steam.

Data are also collected on condensate input and output because the thermal energy input to the mill is the steam input (for example, from a cogeneration plant) minus the condensate returned to the steam supplier.

At most mills, engineers from Paprican visited the mill site for several days to collect the energy and production data from mill staff and mill information systems. This practice ensures a consistent method for the allocation of energy and fibre resources to the energy conversion and manufacturing areas. However, for a few mills, the mill staff, in consultation with a Paprican engineer, recorded the data.

At all mills, the data were recorded in a spreadsheet tool to facilitate data checking and data reconciliation. Paprican collected data from 51 mills: 49 mills in Canada and 2 mills in the United States that were similar to the Canadian operations of the same companies. These mills represent 55 percent of Canadian production capacity and provided data for the major pulping processes and product grades of the Canadian pulp and paper industry.

Allocate and reconcile data
The third step is to allocate the energy and fibre resources to the energy conversion and manufacturing areas. For each area, data are collected on energy inputs and outputs and on fibre inputs and outputs.

For the mechanical pulping area in Figure 2-2, the energy inputs are electricity and the feed water to the reboiler; the energy output is the reboiler steam. The fibre input is chips from wood preparation; the fibre output is TMP.

Ideally, all the energy inputs to the mill would be allocated to areas in the mill and to any energy sales. That is, energy inputs and outputs would balance. Realistically, there will not be a perfect energy balance because of instrument measurement errors and estimations when measurements are unavailable.

The quality of the data is recorded when the energy and fibre data are collected:

- A–reliable instrumentation with good calibration
- B–less reliable instrumentation
- C–calculated by heat and material balance from measured values
- D–estimated when measurements are unavailable

This information is used to weight the corrections needed to reconcile the energy and fibre data.

Calculate energy consumption

The fourth step is to calculate the specific energy consumption for each area from its energy consumption and fibre production, by using the reconciled data. These results allow the mill staff to identify where their operations are least efficient and thereby to identify areas that require changes in operating procedures or capital investments. A sample calculation for a newsprint mill is shown in Appendix B.

3 RESULTS

3. RESULTS

The Pulp and Paper Research Institute of Canada (Paprican) collected energy and production data from 51 mills on a quarterly basis. For most mills, Paprican collected data for four consecutive quarters. For two mills, Paprican could collect data for only one quarter. The data for these two mills were excluded from the analysis, leaving 49 mills in the data set. This section presents the results of the energy benchmarking survey for the manufacturing and energy conversion areas of the 49 pulp and paper mills.

Data analysis

Table 3-1 shows the distribution of mills by pulping process and product type for the 49 pulp and paper mills. Several mills had multiple pulping processes and multiple product types.

Table 3-1 Distribution of mills by pulping process and product type

Total Mills in Data Analysis	49
Mills by Pulping Process	
Mechanical Pulping	28
Kraft Pulping	24
Recycled Pulping	10
Sulphite Pulping	4
Mills by Product Type	
Pulp	27
Newsprint	20
Paper (other than newsprint)	17
Board	5

The difference between the energy inputs (purchased and produced) and energy outputs (consumed and sold) for a mill indicates how well the energy was allocated to the energy conversion and manufacturing areas.

The average and 90th percentile values for the difference between energy inputs and energy outputs are shown in Table 3-2. The largest differences were for steam and condensate.

Table 3-2 Data quality

	Energy Inputs – Energy Outputs (%)†			
	Electricity	Fuel	Steam	Condensate
Average	2.40	1.00	5.70	2.50
90th Percentile	5.90	3.00	12.10	9.50

† There was a difference between energy inputs and energy outputs in data reconciliation.

There were problems in allocating the electricity to the areas. The power distribution and metering were not arranged by area in some cases. Therefore, the total electricity consumption was correct but the allocation to individual areas was not accurate for some mills.

For example, some of the power for the kraft evaporators area were measured in the kraft recovery boiler area. Therefore, the measurements of the electricity consumption for the kraft evaporators are lower than the actual value, and the measured consumption for the kraft recovery boiler is higher than the actual value. However, the power was measured accurately in areas such as mechanical pulping and turbogenerators, where there was significant electricity consumption or production.

Manufacturing areas

The energy consumption and production of the manufacturing areas are shown in Tables 3-3 to 3-12. The tables show the 25th percentile, median and 75th percentile specific energies for each area.*

For most areas, the fibre allocated to the area was equal to the fibre produced by the area.

For kraft evaporators and recausticizing, the fibre allocation was the unbleached kraft pulp produced in the kraft pulping area.

For the sulphite acid plant, the fibre allocation was the unbleached sulphite pulp produced in the sulphite pulping area.

For the common areas, the fibre allocated was the total mill production.

The tables also show the energy values (adapted from recent literature)[4, 5] for the manufacturing areas that use modern technology.

* *The k percentile is the value of a distribution with k percentage of the values equal to or below it. Thus, the 25th percentile value is equal to or greater than 25 percent of the values of the distribution; the median (50th percentile) value is equal to or greater than 50 percent of the values; the 75th percentile value is equal to or greater than 75 percent of the values.*

[4] Towers, M.T. and D.W. Francis. *Impact of Mill Modernization on Energy Use and Greenhouse Gas Emissions*, PACWEST Conference, Harrison Hot Springs, British Columbia, May 7–10, 2003.

[5] Browne, T.C and P.N. Williamson, eds. *Energy Cost Reduction in the Pulp and Paper Industry*, Pulp and Paper Research Institute of Canada, Montréal, 1999.

Be careful when making direct comparisons of the energy data in this report with reports of best practices. The data for best practices are derived from several sources, and those sources can draw area boundaries in different ways, or they may apply only to specific technologies.

In addition, the definition of thermal energy (the steam consumed minus the condensate returned to the boiler) may not be the same in various reports. Consequently, use these comparisons with best practices as general guides only.

Table 3-3 Electricity consumption of pulp manufacturing areas

	Electricity Consumption (kWh/ODt)†			
	25th Percentile	Median	75th Percentile	Modern
Wood Preparation	9.50	22.20	31.60	22.00
Kraft Pulping – Continuous	150.50	179.50	221.30	161.00
Kraft Pulping – Batch	134.90	169.30	230.50	161.00
Kraft Pulping – M&D	166.00	190.90	208.70	NA
Kraft Evaporators – Indirect Contact	0.00	15.70	30.60	33.00
Kraft Evaporators – Direct Contact	10.00	24.50	44.70	NA
Kraft Recausticizing	23.20	32.10	47.90	56.00
Kraft Bleaching – Softwood	112.30	179.50	240.70	122.00
Kraft Bleaching – Hardwood	117.10	143.90	237.50	NA
Sulphite Pulping	226.50	766.40	1358.80	NA
Sulphite Acid Plant	–	32.00	–	NA
Mechanical Pulping – TMP for Newsprint	2508.60	2661.60	2786.80	2450.00 to 2600.00
Mechanical Pulping – TMP for Paper	2586.60	2943.20	3261.10	2650.00 to 2800.00
Mechanical Pulping – SGW	1690.80	1780.30	2081.70	1500.00 to 1800.00
Mechanical Peroxide Bleaching	84.10	133.80	232.50	NA
Recycled Pulping	256.10	344.20	428.60	460.00

† The specific energy is the electricity consumed divided by the fibre produced or allocated to the area expressed on an oven-dried basis. The paper grades for mechanical pulping – TMP for paper include uncoated groundwood specialties and printing and writing paper; some of the pulp may also be used for newsprint.

The energy consumption and production of various manufacturing areas are shown in Figures 3-1 to 3-8. The mills that followed best practices used the least energy. The variations in energy consumption for each area indicate the realistic potential for energy reductions.

The mechanical pulping areas in pulp manufacturing used the most energy. The distribution of electricity consumption for the mechanical pulping area producing TMP for newsprint is shown in Figure 3-1. The lowest electricity consumption value is suspect. The variation of the remaining values is related to wood species primarily, not to operating practices.

Figure 3-1 Electricity consumption for a mechanical pulping area producing TMP for newsprint

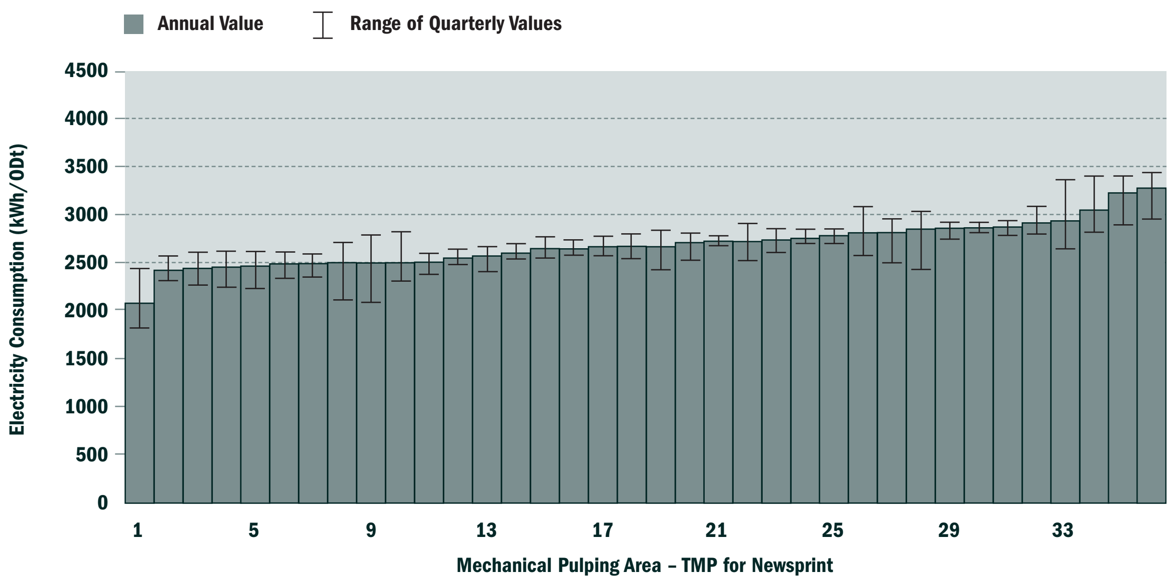


Table 3-4 Fuel consumption of pulp manufacturing areas

	Fuel Consumption (GJ/ODt)†			
	25th Percentile	Median	75th Percentile	Modern
Kraft Recausticizing	1.96	2.15	2.34	1.70

† The specific energy is the fuel consumed divided by the fibre produced or allocated to the area expressed on an oven-dried basis.

The largest fuel consumption for pulp manufacturing occurred in the kraft recausticizing area. The fuel is used in the lime kiln. The distribution of fuel consumption for the kraft recausticizing area is shown in Figure 3-2.

Figure 3-2 Fuel consumption for a kraft recausticizing area

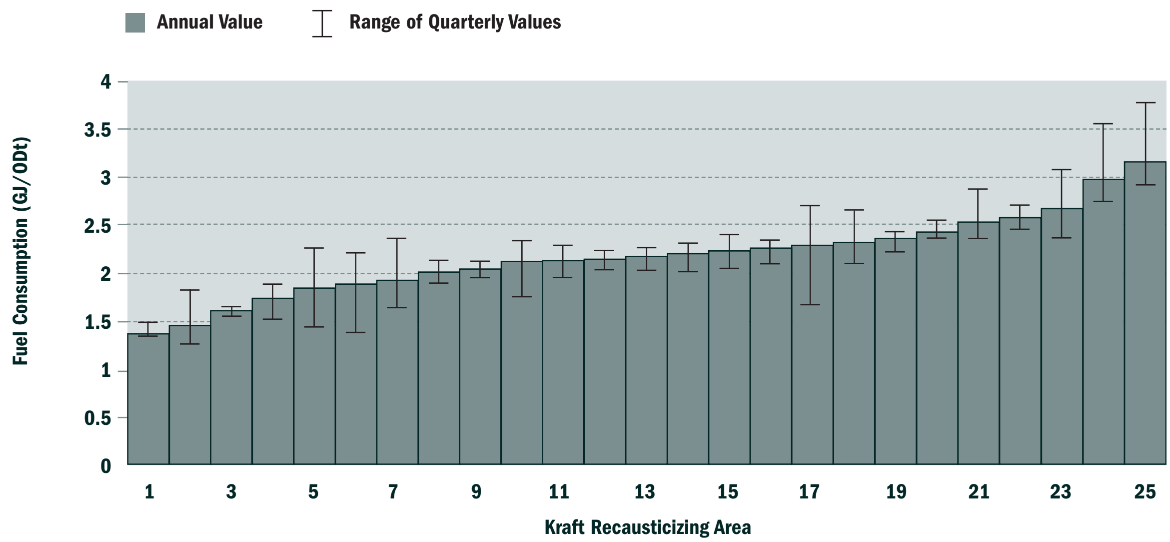


Table 3-5 Thermal energy consumption of pulp manufacturing areas

	Thermal Energy Consumption (GJ/ODt)†			
	25th Percentile	Median	75th Percentile	Modern
Wood Preparation	0.00	0.00	0.00	0.00
Kraft Pulping – Continuous	2.43	2.94	3.81	2.20
Kraft Pulping – Batch	4.33	4.94	5.64	3.50
Kraft Pulping – M&D	5.50	6.04	6.76	NA
Kraft Evaporators – Indirect Contact	5.03	5.91	7.06	3.20
Kraft Evaporators – Direct Contact	2.90	2.96	3.89	NA
Kraft Recausticizing	0.00	0.14	0.44	0.00
Kraft Bleaching – Softwood	2.57	3.41	4.65	1.70
Kraft Bleaching – Hardwood	1.62	2.33	3.37	NA
Sulphite Pulping	4.11	5.00	6.48	NA
Sulphite Acid Plant	0.00	–	–	NA
Mechanical Pulping – TMP for Newsprint	0.39	0.56	0.80	0.00
Mechanical Pulping – TMP for Paper	0.03	0.67	0.93	0.00
Mechanical Pulping – SGW	0.00	0.00	0.00	0.00
Mechanical Peroxide Bleaching	0.00	0.00	0.13	0.00
Recycled Pulping	0.00	0.11	0.44	0.00

† The specific energy is the thermal energy consumed divided by the fibre produced or allocated to the area expressed on an oven-dried basis.

Thermal energy consumption for some kraft pulp manufacturing areas are shown in Figures 3-3 to 3-5. Although the median value for kraft pulping with a continuous digester (Figure 3-3) is lower than that for pulping with a batch digester (Figure 3-4), some batch digester areas consume less thermal energy than some continuous digester areas. This fact indicates that both technology and operating practices affect the energy consumption.

Figure 3-3 Thermal energy consumption of a kraft pulping area with a continuous digester

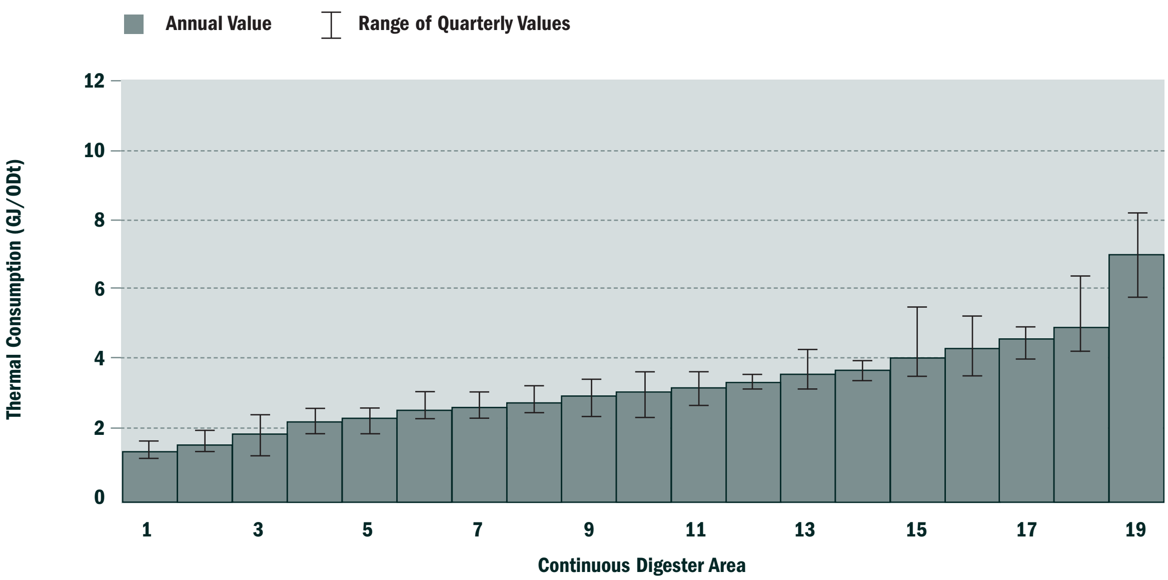


Figure 3-4 Thermal energy consumption of a kraft pulping area with a batch digester

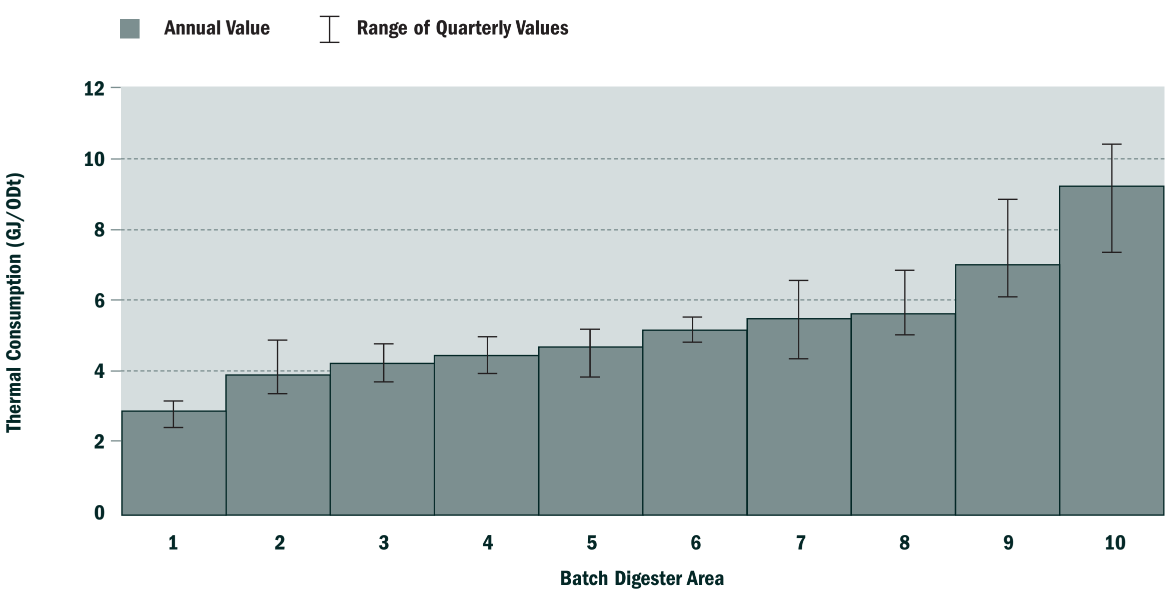


Figure 3-5 Thermal energy consumption for a kraft pulp bleaching area for softwood pulp

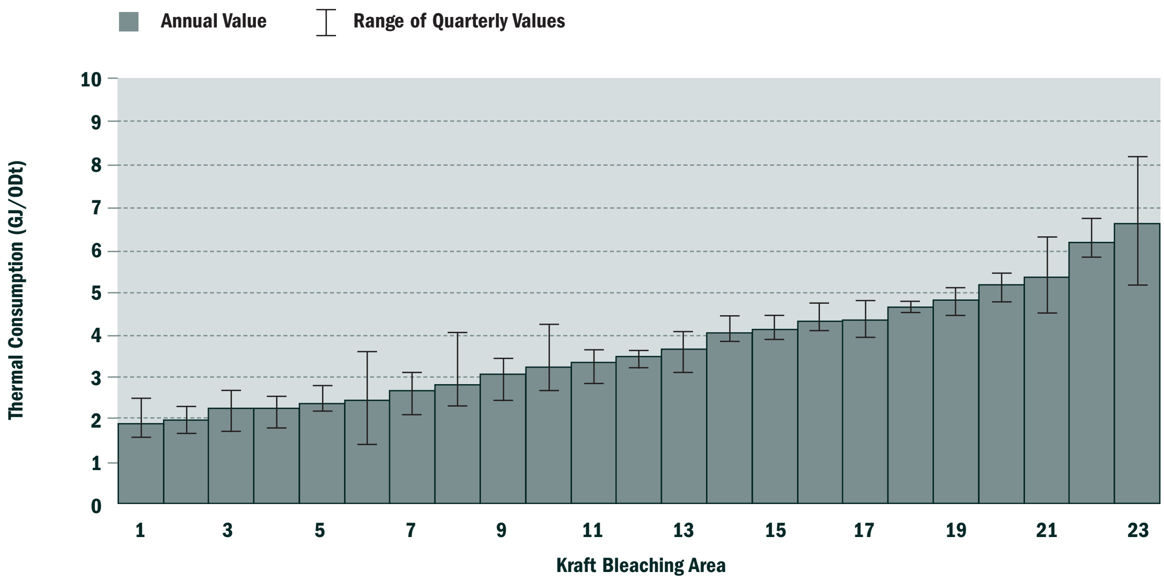


Table 3-6 Thermal energy production of pulp manufacturing areas

	Thermal Energy Production (GJ/ODt)†			
	25th Percentile	Median	75th Percentile	Modern
Mechanical Pulping – TMP for Newsprint	0.00	0.00	3.50	5.00 to 5.50
Mechanical Pulping – TMP for Paper	0.00	0.00	1.04	5.50 to 6.00

† The specific energy is the thermal energy produced divided by the fibre produced or allocated to the area expressed on an oven-dried basis.

Thermomechanical pulping produces a large amount of thermal energy that can be recovered with a reboiler as clean steam. The net thermal energy production for the area is the thermal energy of the steam production less the thermal energy consumption.

The net thermal energy production for mechanical pulping areas that produce TMP for newsprint is shown in Figure 3-6. Negative values represent net thermal energy consumption. Seventeen of the 36 TMP lines recover thermal energy to produce steam.

Figure 3-6 Net thermal energy production for a mechanical pulping area producing TMP for newsprint

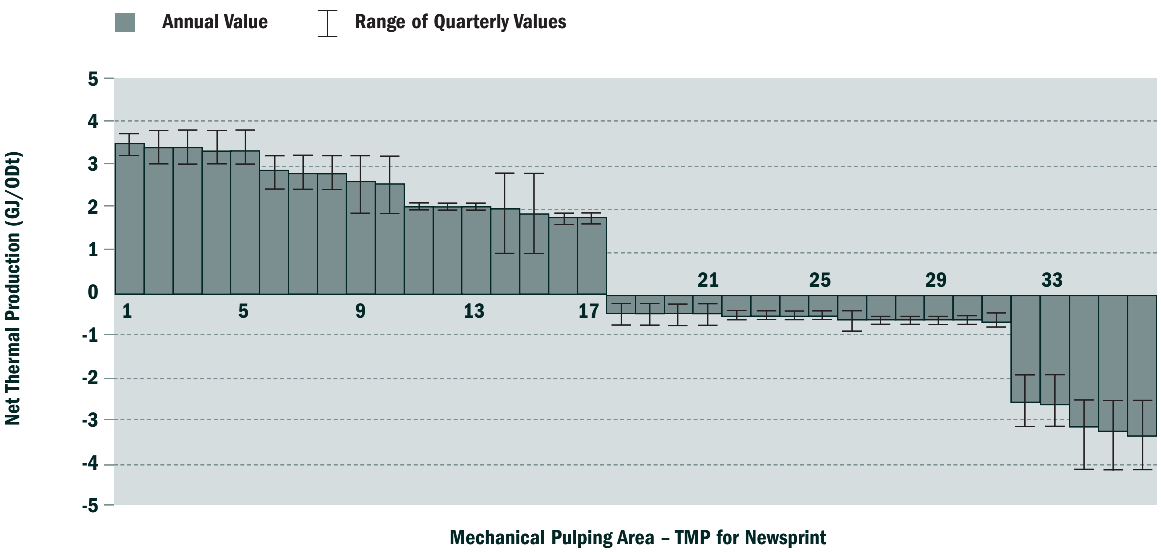


Table 3-7 Electricity consumption of product manufacturing areas

	Electricity Consumption (kWh/ADt)†			
	25th Percentile	Median	75th Percentile	Modern
Paper Machine – Newsprint	502.90	565.20	622.40	330.00
Paper Machine – Uncoated Ground wood	559.10	677.00	777.10	NA
Paper Machine – Printing and Writing	595.80	662.50	706.70	550.00
Paper Machine – Kraft Papers	823.90	1021.50	1108.80	NA
Board Machine	493.40	555.00	637.90	515.00
Pulp Machine – Steam Dryer	119.10	153.20	191.30	141.00
Pulp Machine – Wet Lap	67.20	71.20	100.90	NA
Converting Operation	57.50	87.20	129.10	NA

† The specific energy is the electricity consumed divided by the fibre produced expressed on an air-dried basis.

Thermal energy consumption for various product manufacturing areas are shown in Figures 3-7 and 3-8. Although the median value for paper machine areas that produce newsprint (Figure 3-7) is lower than that for uncoated groundwood specialties (Figure 3-8), some paper machine areas that produce uncoated ground wood specialties consume less thermal energy than some areas that produce newsprint.

Figure 3-7 Thermal energy consumption for a paper machine area producing newsprint

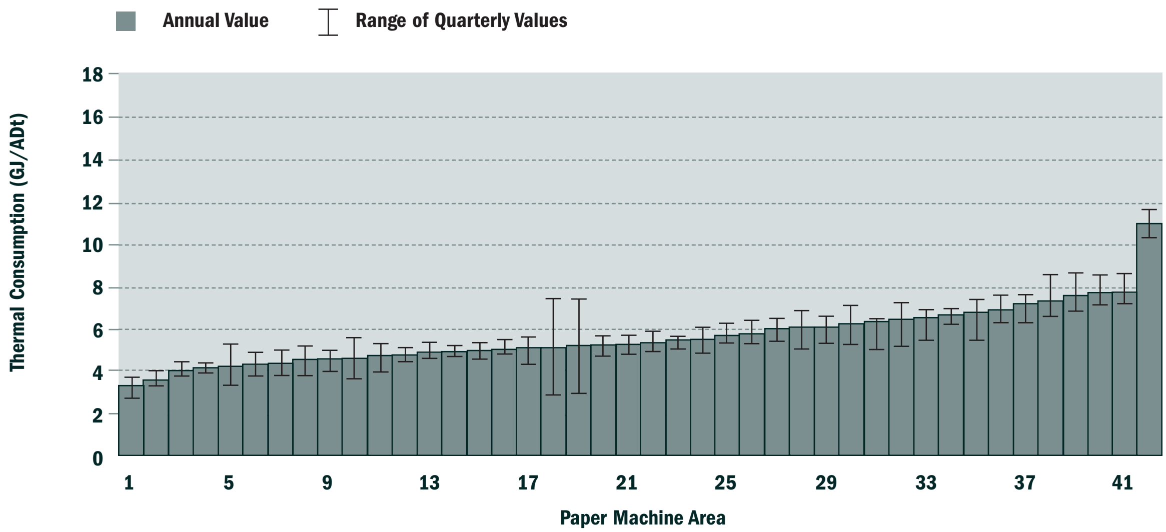


Figure 3-8 Thermal energy consumption for a paper machine area producing uncoated ground wood specialties

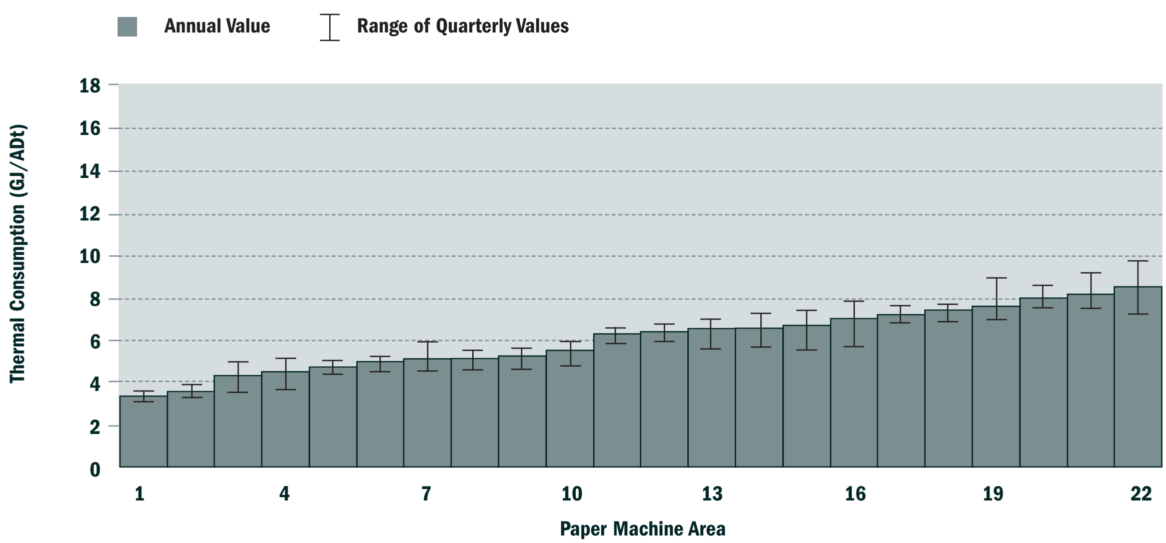


Table 3-8 Fuel consumption of product manufacturing areas

	Fuel Consumption (GJ/ADt)†			
	25th Percentile	Median	75th Percentile	Modern
Board Machine	0.37	0.49	0.51	0.00

† The specific energy is the fuel consumed divided by the fibre produced or allocated to the area expressed on an air-dried basis.

Table 3-9 Thermal energy consumption of product manufacturing areas

	Thermal Energy Consumption (GJ/ADt)†			
	25th Percentile	Median	75th Percentile	Modern
Paper Machine – Newsprint	4.77	5.36	6.62	4.90
Paper Machine – Uncoated Groundwood	4.93	6.21	7.01	NA
Paper Machine – Printing and Writing	5.74	6.32	8.31	5.10
Paper Machine – Kraft Papers	8.47	9.10	9.11	NA
Board Machine	6.92	6.94	7.18	3.40
Pulp Machine – Steam Dryer	4.14	4.59	5.26	2.30
Pulp Machine – Wet Lap	0.00	0.00	0.00	NA
Converting Operation	0.00	0.00	0.00	NA

† The specific energy is the thermal energy consumed divided by the fibre produced or allocated to the area expressed on an air-dried basis.

Table 3-10 Electricity consumption of common areas

	Electricity Consumption (kWh/ADt)†			
	25th Percentile	Median	75th Percentile	Modern
Water Treatment	13.80	29.00	54.60	32.00
Effluent Treatment – Activated Sludge	31.80	49.40	80.60	30.00
Effluent Treatment – Aerated Lagoon	34.30	47.60	70.80	30.00
General/Buildings	5.20	14.40	55.30	NA

† The specific energy is the electricity consumed divided by the fibre allocated to the area expressed on an air-dried basis.

Table 3-11 Fuel consumption of common areas

	Fuel Consumption (GJ/ADt)†			
	25th Percentile	Median	75th Percentile	Modern
General/Buildings	0.00	0.04	0.07	NA

† The specific energy is the fuel consumed divided by the fibre allocated to the area expressed on an air-dried basis.

Table 3-12 Thermal energy consumption of common areas

	Thermal Energy Consumption (GJ/ADt)†			
	25th Percentile	Median	75th Percentile	Modern
Water Treatment	0.00	0.00	0.00	NA
Effluent Treatment – Activated Sludge	0.00	0.00	0.00	NA
Effluent Treatment – Aerated Lagoon	0.00	0.00	0.17	NA
General/Buildings	0.00	0.19	0.51	NA

† The specific energy is the thermal energy consumed divided by the fibre allocated to the area expressed on an air-dried basis.

Energy conversion areas

The energy consumption and production of the energy conversion areas are shown in Tables 3-13 to 3-20. The tables show the 25th percentile, median and 75th percentile specific energy consumption for each area. The tables also show the energy values adapted from recent literature[6, 7] for the manufacturing areas that use modern technology.

In Tables 3-13 to 3-15, the energy consumption is expressed in terms of thermal energy produced by the boilers. The thermal energy production is equal to the steam produced minus the condensate (boiler feed water) consumed.

Table 3-13 Electricity consumption of boiler areas

	Electricity Consumption (kWh/GJ)†			
	25th Percentile	Median	75th Percentile	Modern
Power Boiler	2.60	6.80	10.50	NA
Kraft Recovery Boiler – Low Odour	3.10	5.20	7.20	4.00
Kraft Recovery Boiler – Direct Contact	4.80	9.00	10.90	NA

† The specific energy is the electricity consumed divided by the thermal energy produced by the boiler.

Table 3-14 Fuel consumption of boiler areas

	Fuel Consumption (GJ/GJ)†			
	25th Percentile	Median	75th Percentile	Modern
Power Boiler	1.28	1.38	1.67	1.20
Kraft Recovery Boiler – Low Odour	1.45	1.56	1.65	1.40
Kraft Recovery Boiler – Direct Contact	1.79	2.02	2.13	NA

† The specific energy is the fuel consumed divided by the thermal energy produced by the boiler.

6 Towers, M.T. and D.W. Francis. *Impact of Mill Modernization on Energy Use and Greenhouse Gas Emissions*, PACWEST Conference, Harrison Hot Springs, British Columbia, May 7–10, 2003.

7 Browne, T.C and P.N. Williamson, eds. *Energy Cost Reduction in the Pulp and Paper Industry*, Pulp and Paper Research Institute of Canada, Montréal, 1999.

Table 3-15 Thermal energy consumption of boiler areas

	Thermal Energy Consumption (GJ/GJ)†			
	25th Percentile	Median	75th Percentile	Modern
Power Boiler	0.00	0.02	0.06	0.00
Kraft Recovery Boiler – Low Odour	0.11	0.14	0.19	0.05
Kraft Recovery Boiler – Direct Contact	0.14	0.16	0.17	NA

† The specific energy is the thermal energy consumed divided by the thermal energy produced by the boiler.

In Tables 3-16 to 3-18, the energy consumption and net thermal energy production are expressed in terms of unbleached kraft pulp produced in the kraft pulping area. The net thermal energy is the thermal energy produced by the recovery boiler minus the thermal energy used by the recovery boiler (for example, for soot blowing).

Table 3-16 Electricity consumption of kraft recovery boilers

	Electricity Consumption (kWh/ODt)†			
	25th Percentile	Median	75th Percentile	Modern
Kraft Recovery Boiler – Low Odour	54.60	82.60	112.00	70.00
Kraft Recovery Boiler – Direct Contact	73.50	100.60	133.40	NA

† The specific energy is the electricity consumed divided by the fibre allocated to the area expressed on an oven-dried basis.

Table 3-17 Fuel consumption of kraft recovery boilers

	Fuel Consumption (GJ/ODt)†			
	25th Percentile	Median	75th Percentile	Modern
Kraft Recovery Boiler – Low Odour	26.16	28.78	29.61	NA
Kraft Recovery Boiler – Direct Contact	22.34	26.39	30.79	NA

† The specific energy is the fuel consumed divided by the fibre allocated to the area expressed on an oven-dried basis.

Table 3-18 Net thermal energy production of kraft recovery boilers

	Net Thermal Energy Production (GJ/ODt)†			
	25th Percentile	Median	75th Percentile	Modern
Kraft Recovery Boiler – Low Odour	13.45	14.63	16.72	NA
Kraft Recovery Boiler – Direct Contact	9.66	10.58	11.84	NA

† The net thermal energy is the thermal energy produced by the recovery boiler minus the thermal energy used by the recovery boiler, for example, for soot blowing. The specific energy is the net thermal energy produced divided by the fibre allocated to area expressed on an oven-dried basis.

The thermal energy consumption for power generation is expressed in terms of the electricity generated. See Table 3-19. The specific energy is the thermal energy consumed divided by the electricity generated.

Table 3-19 Thermal energy consumption of generators

	Thermal Energy Consumption (MJ/kWh)†			
	25th Percentile	Median	75th Percentile	Modern
Back-Pressure Turbine – Electricity	3.71	3.77	4.36	3.70
Condensing Turbine – Electricity	8.68	9.74	14.14	8.60

† The specific energy is the thermal energy consumed divided by the electricity generated.

The deaerator produces boiler feed water from condensate, make-up water and steam. The net thermal energy produced for the deaerator does not provide useful information because it is equal to the enthalpy of the water make-up minus any heat losses.

Instead of reporting the specific thermal energy produced for the deaerator, Paprican calculated the steam consumption at the deaerator at each mill as a percentage of the total steam production. See Table 3-20.

Table 3-20 Steam consumption of deaerators

	Steam Consumption (%)†			
	25th Percentile	Median	75th Percentile	Modern
Deaerator	5.90	8.30	11.00	5.00

† The steam consumption is the steam consumed by the deaerator divided by the total steam produced by the boilers. This steam consumption is related to the percent condensate return for the mill.

4 DISCUSSION

4. DISCUSSION

The mill staff can use the energy data to make meaningful benchmarking comparisons of energy use by area. Comparisons can be made among areas that produce the same product with the same technology, even though the mills use different product mixes and technologies.

The variations in energy consumption for each area indicate the realistic potential for energy reductions.

Additional insights on mill energy use can be made by combining areas at mill sites that produce similar products to allocate the energy consumption to product grades. This process can be done for mills that produce a single product and for mills that produce multiple products, because the energy and fibre data are available by area. The energy allocation to two products, kraft pulp and newsprint from TMP, is discussed in the following sections.

Kraft pulp

Twenty-four mills have kraft pulping operations that produce unbleached kraft pulp as an intermediate product. The analysis combined the following areas for manufacturing unbleached kraft pulp:

- kraft pulping
- kraft recausticizing
- kraft evaporators
- kraft recovery boiler

Other areas, such as wood preparation and effluent treatment, were not included in this analysis.

The average energy use for manufacturing unbleached kraft pulp at the 24 mill sites is shown in Table 4-1.

Table 4-1 Energy consumption and production for unbleached kraft pulp

	Electricity Consumption (kWh/ODt)†	Fuel Consumption (GJ/ODt)†	Thermal Energy Consumption (GJ/ODt)†	Thermal Energy Production (GJ/ODt)†	Net Thermal Energy Production (GJ/ODt)†
25th Percentile	289.40	26.22	9.27	14.75	5.91
Median	331.30	30.02	11.28	16.43	4.44
75th Percentile	391.10	31.71	14.07	18.37	2.02
Modern	260.00	NA	7.10	NA	NA

† The specific energy is determined from the sum of energies for the following areas in each mill: kraft pulping, kraft recausticizing, kraft evaporators and kraft recovery boiler. The specific energy is the total energy divided by the unbleached kraft pulp production. The pulp production is expressed on an oven-dried basis.

The specific fuel consumption for bleached kraft pulp in Table 4-2 is greater than that for unbleached kraft pulp because of pulp shrinkage during bleaching, even though no fuel is consumed in the kraft bleaching area.

The pulp bleaching area produces less bleached kraft pulp than the unbleached kraft pulp it consumes. Similarly, the specific thermal energy production for bleached kraft pulp is greater than that for unbleached kraft pulp, even though no thermal energy is produced in the kraft bleaching area.

Table 4-2 Energy consumption and production for bleached kraft pulp

	Electricity Consumption (kWh/ODt)†	Fuel Consumption (GJ/ODt)†	Thermal Energy Consumption (GJ/ODt)†	Thermal Energy Production (GJ/ODt)†	Net Thermal Energy Production (GJ/ODt)†
25th Percentile	455.20	27.72	12.71	16.19	3.60
Median	550.30	32.53	16.27	18.05	1.32
75th Percentile	633.80	34.12	18.51	19.79	– 0.22
Modern	370.00	NA	8.60	NA	NA

† The specific energy is determined from the sum of energies for the following areas in each mill: kraft pulping, kraft recausticizing, kraft evaporators, kraft recovery boiler and kraft bleaching. The specific energy is the total energy divided by the bleached kraft pulp production. The pulp production is expressed on an oven-dried basis.

Twenty mills produce bleached kraft market pulp as a final product. In the analysis, the following areas were combined for manufacturing bleached kraft market pulp:

- kraft pulping
- kraft recausticizing
- kraft evaporators
- kraft recovery boiler
- kraft bleaching and pulp machine

The average energy use for manufacturing bleached kraft market pulp at the 20 mills is also shown in Table 4-3 and Figures 4-1 to 4-5.

Table 4-3 Energy consumption and production for manufacturing bleached kraft market pulp

	Electricity Consumption (kWh/ADt)†	Fuel Consumption (GJ/ADt)†	Thermal Energy Consumption (GJ/ADt)†	Thermal Energy Production (GJ/ADt)†	Net Thermal Energy Production (GJ/ADt)†
25th Percentile	586.30	27.10	16.59	14.98	0.94
Median	666.60	30.07	19.57	16.40	3.48
75th Percentile	726.80	30.79	21.43	17.75	4.38
Modern	511.00	NA	10.90	NA	NA

† The specific energy is determined from the sum of energies for the following areas in each mill: kraft pulping, kraft recausticizing, kraft evaporators, kraft recovery boiler, kraft bleaching and pulp machine. The specific energy is the total energy divided by the bleached kraft market pulp production. The pulp production is expressed on an air-dried basis.

Figure 4-1 Electricity consumption for manufacturing bleached kraft market pulp

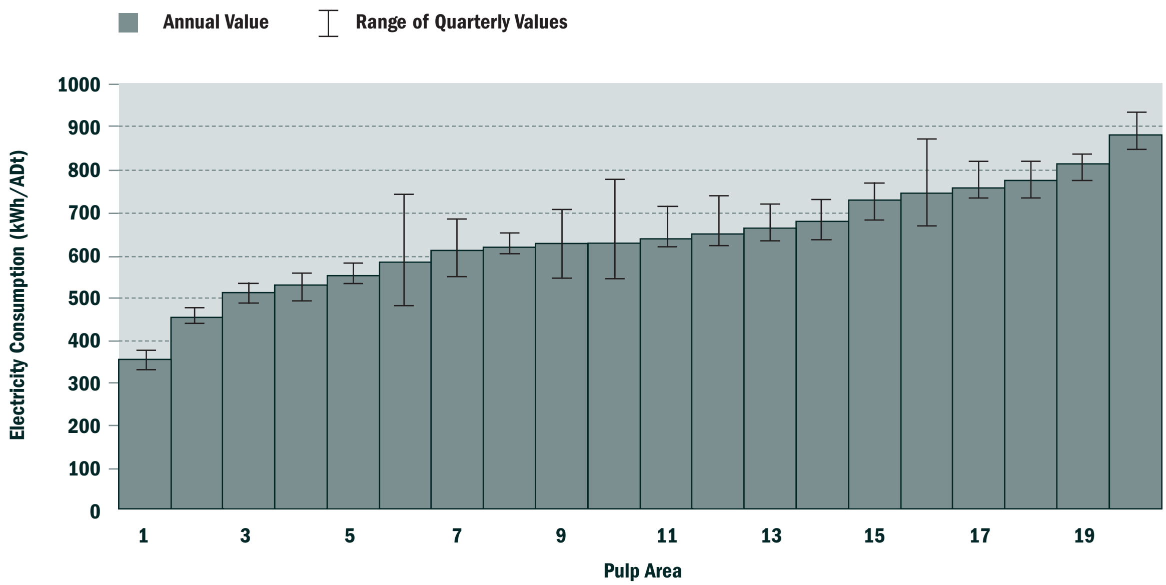
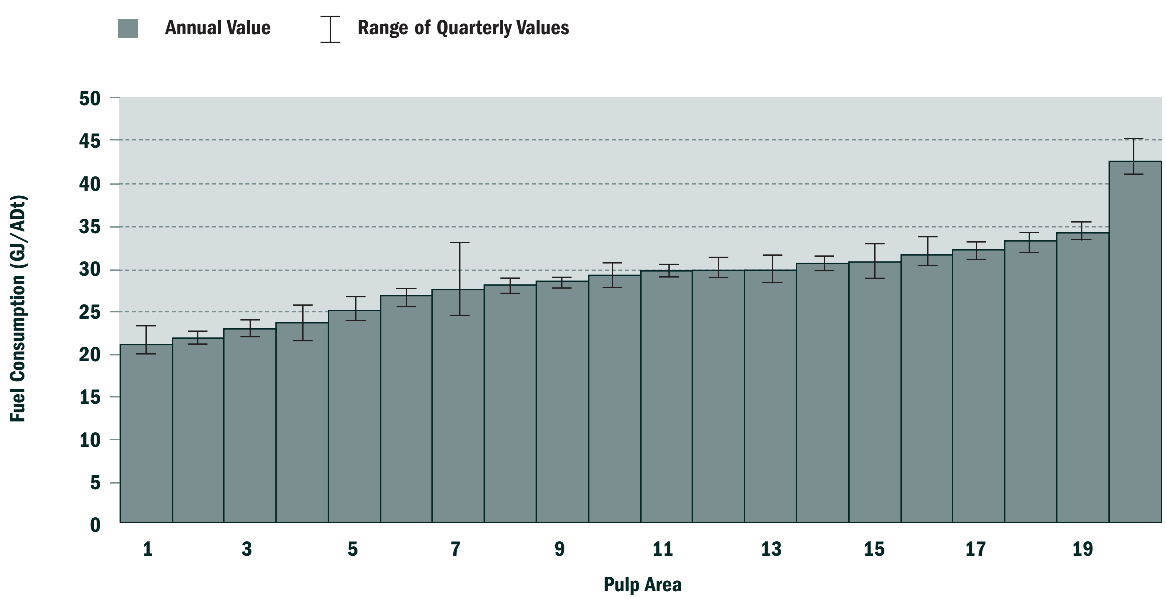
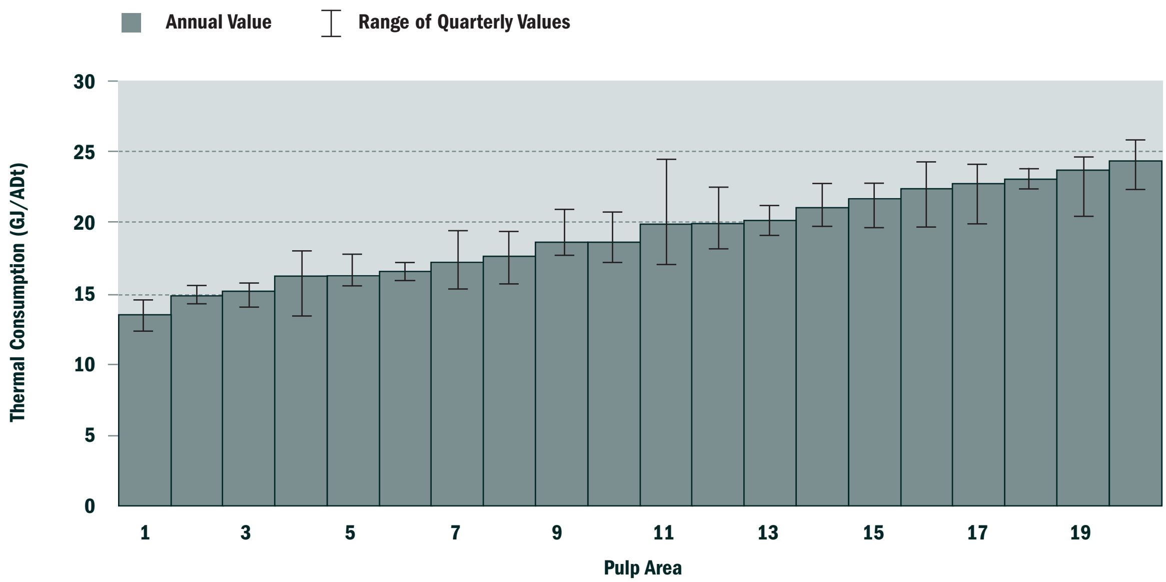


Figure 4-2 Fuel consumption for manufacturing bleached kraft market pulp*



* Fuel consumption includes spent pulping liquor and fossil fuel.

Figure 4-3 Thermal energy consumption for manufacturing bleached kraft market pulp



Newsprint

Newsprint furnish consists of mostly mechanical pulp but can contain chemical pulp and recycled pulp. The mechanical pulps for the 20 newsprint mills in this study were thermomechanical pulp (TMP) and stone groundwood pulp (SGW). The chemical pulps were kraft pulp and sulphite pulp.

The energy required to manufacture newsprint depends in part on the furnish content, because each of the pulping processes consume different levels of energy. See Table 4-4.

Seven of the 28 mills that have mechanical pulping produced newsprint solely from TMP. The energy allocated to manufacturing newsprint from TMP is shown in Table 4.2 and in Figures 4.4 and 4.5.

Table 4-4 Energy consumption and production for manufacturing newsprint

	Electricity Consumption (kWh/ADt)†	Fuel Consumption (GJ/ADt)†	Thermal Energy Consumption (GJ/ADt)†	Thermal Energy Production (GJ/ADt)†	Net Thermal Energy Production (GJ/ADt)†
25th Percentile	2779.30	0.00	5.54	0.00	2.63
Median	2908.50	0.00	6.10	2.81	5.31
75th Percentile	2970.10	0.00	6.80	3.33	5.95
Modern	2620.00 to 2760.00	0.00	4.90	4.70 to 5.10	– 0.20 to 0.20

† The specific energy is determined from the sum of energies for the following areas: mechanical pulping – TMP for newsprint and paper machine. The specific energy is the energy divided by the newsprint production. The newsprint production is expressed on an air-dried basis.

Figure 4-4 Electricity consumption for manufacturing newsprint from TMP

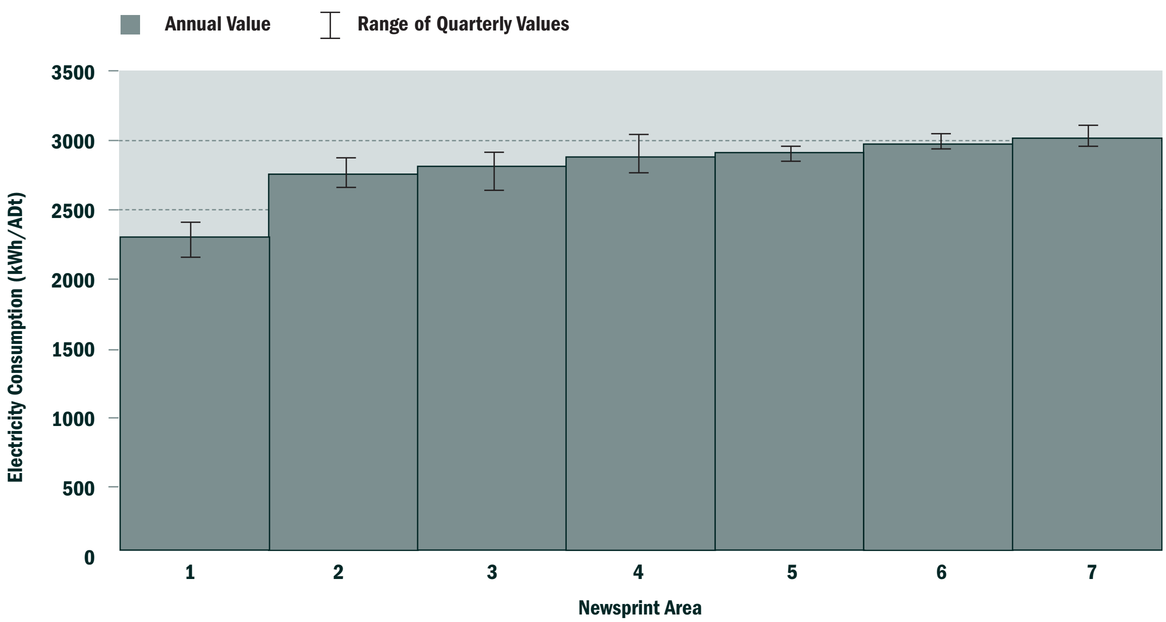
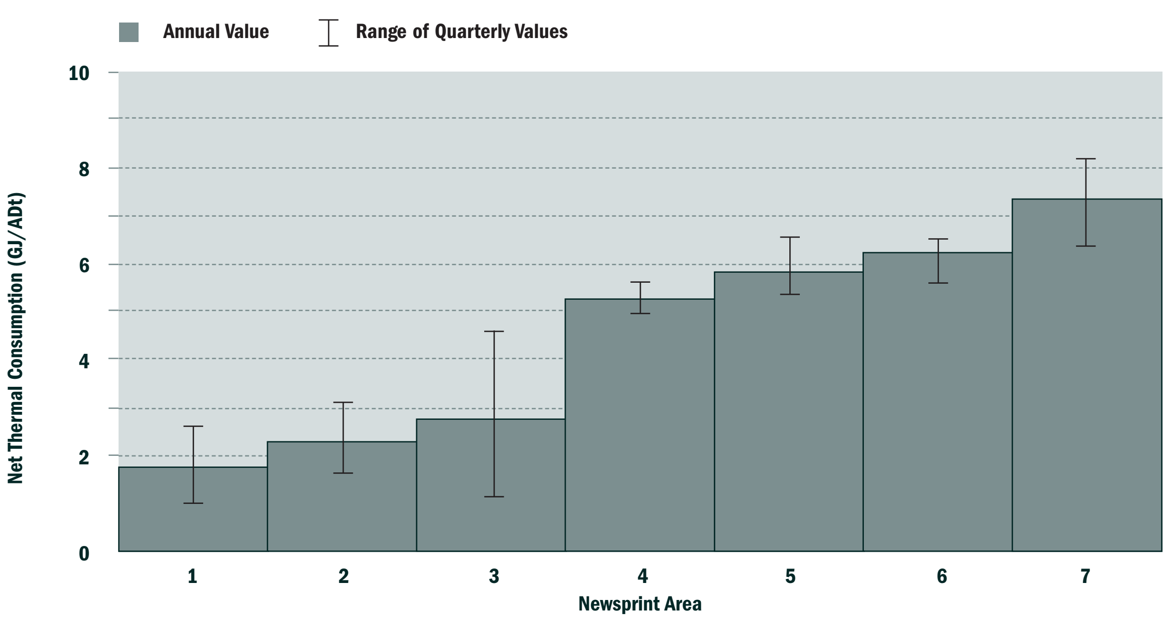


Figure 4-5 shows the net thermal energy consumption for manufacturing newsprint from TMP. That consumption is the thermal energy consumed in the TMP and paper machine areas minus the thermal energy produced in the TMP area. This measurement is the amount of steam that the power boiler must provide.

The mills that consume less net thermal energy have TMP heat recovery (thermal energy produced) and higher humidity dryer hoods (low thermal energy consumed). The mills that consume more net thermal energy do not have TMP heat recovery (no thermal energy produced) and may have lower humidity dryer hoods (high thermal energy consumed).

Figure 4-5 Net thermal energy consumption for manufacturing newsprint from TMP*



* The net thermal energy consumption is the thermal energy consumed in the TMP and paper machine areas minus the thermal energy produced in the TMP area.

5 INTERPRETATION OF THE RESULTS

5. INTERPRETATION OF THE RESULTS

Reasons for the range of values obtained from the benchmarking study will vary from mill to mill:

- The data collecting process did not consider where water is heated in the mill. A mill where steam is used for water heating in the paper machine area will report higher levels of steam use there, even though the hot water might be used elsewhere, than a mill where steam heating of water takes place in the pulp mill.

  Consequently, this second mill will appear to be inefficient in the pulping area. Thus, high consumption in one area may be offset by low consumption elsewhere, because of reasons that have little to do with basic process requirements. Mill staff need to consider the entire site, as well as each process area, independently.

- Production rate and efficiency affect the benchmarking results. Low paper machine efficiency leads to high energy use, because finished, dried paper is reslushed and dried again.

- Downtime for market reasons affects energy use.

- Smaller production lines require more energy per tonne of product than larger mills.

The energy consumption for a process area is determined by three factors:
- product requirements
- technology used
- operating practices

Producing certain products is more energy-intensive than for others, and this will be part of the cost of doing business in that particular market niche.

Some products require more energy to achieve product quality. For example, making thermomechanical pulp (TMP) for printing papers uses more electrical energy than making TMP for newsprint. Mechanical grades for newsprint do not need as much refining power as for Light Weight Coated (LWC) or Super Calendered (SC) grades. After the base stock is dried, coated grades require an extra drying stage for the coating formulation. These product-based constraints also impose limits on energy use reduction.

Different technologies use varying amounts of energy to make the same product.

For example, kraft pulping with batch digesters uses more thermal energy than kraft pulping with continuous digesters. Even the best batch digesters are better than old and inefficient continuous digesters.

For example, only limited energy savings can be achieved with open dryer hoods, older press sections or dryer siphon systems, atmospheric-discharge refiners, or TMP plants that do not have heat recovery equipment, unless a significant capital investment is made. By comparing the energy consumption for different technologies that make the same product, mill staff can determine the potential for energy reductions from major capital investments.

For an individual process area defined by its product and technology, the variation in energy consumption results from how the technology is applied and from operating practices. By determining the settings on valves, water temperatures, and soot blowers, mills can identify the energy use and base efficiency of the operation. Leaking valves, malfunctioning steam traps, mechanical seals and packings, and improper maintenance can all have an impact on the energy efficiency of mill operations.

The study revealed that best practices are near the theoretical minimum for certain process areas. The variations in energy consumption for each area indicate the realistic potential for energy reductions.

5.1 How do the results affect my mill?

Mill staff can use the energy data to make meaningful benchmarking comparisons of energy use by area. Comparisons can be made between areas that produce the same product with the same technology, even though the mills might differ in their product mix. This comparison allows mill staff to identify where their operations are less efficient and thereby identify areas that require changes in operating procedures or capital investments.

Benchmarking can prompt questions such as “Why is the energy use for my kraft pulping area so much higher than in other mills?” or more general questions such as, “Where does my mill stand?” or “Why is my mill’s performance poor in one area and best in class in another area?”

It is in answering these questions that mill staff can make the appropriate changes in their operations to reduce energy consumption. These answers are site specific, depending on the reasons for the high energy consumption.

5.2 What steps do I take?

You must analyse the results of the benchmarking to determine how to improve energy efficiency in your mill. The following steps suggest how to proceed.

Step 1a. **Compare your facility to other facilities**
External comparisons help to determine how your level of energy consumption compares to other mill operations. If you did not participate in this benchmarking study, use the described benchmarking method to determine the energy consumption for your own process areas. Refer to the attached CD for instructions on how to benchmark your own mill. Consider the reasons for high energy use listed in Section 5, and see which ones apply to your situation. Compare your mill's process areas to see where you stand relative to others; this will identify the biggest gaps. What level of consumption is achievable with the best operating practices and industry benchmarks? These external comparisons will be valuable in developing realistic initial savings expectations.

Step 1b. **Compare your facility to itself**
Internally, you may be able to perform historical comparisons with data that is already available. Variation from month to month in your level of energy efficiency is easily identifiable. Determining the cause of and minimizing this variation will yield savings. Ongoing analysis and strategic communication will sustain your improvements and assist in refining your continuing savings expectations.

Step 2. **Establish an energy-management program**
Take a structured approach to setting up an energy-management program. This involves identifying key staff and giving them the tools and authority to make changes. Nominating an energy champion to create awareness, set targets, develop action plans, monitor progress, implement projects, communicate results, and celebrate success will demonstrate to all employees the importance of an energy-management program. This energy champion and the team must develop an energy policy that is aligned with the company's strategic goals and set priority objectives that are publicized to all staff.

Step 3. Understand when energy is used

The cost of electricity is affected by the level of demand and the time of day. The electrical demand profile shows the rate of electricity consumption over time. This electrical fingerprint is a critical element in understanding use patterns. As well, understanding the demand for gas, steam and compressed air over time provides valuable insight into how theses energies can also be managed effectively.

Step 4. Understand where energy is used

Treat energy as you do any other purchased commodity. Building an inventory of your electrical loads and uses of thermal energy will help you focus on the largest and, consequently, the most expensive, consumers.

Some suggestions to help you understand how and when energy is used in your mill are: renewing instrumentation; updating metering equipment; and rewiring to study energy flows by operation. This will help a mill to identify the specific consumption of key equipment centres and determine the associated energy costs.

Step 5. Eliminate waste

The first and most important step in realizing savings opportunities is to match what you use to what is required. The key considerations here are the duration of use and magnitude of use. Waste may occur in many forms including excess operating time, volume and in quality such as pressure and temperature.

Step 6. Maximize (system) efficiency

After the need and use are matched properly, the next step is to ensure that the components of the system that meet the need are operating as efficiently as possible. In this step, the impact of operating conditions, maintenance and equipment/technology are considered.

Looking at efficiency from a systems perspective is critical in this step. Mills can consider larger process optimization studies using Pinch analysis to identify energy reduction projects. Mills can also look at boiler optimization studies, which can lead to improvements in steam generated from black liquor and wood waste. These improvements allow a reduction in fossil fuel use, increased throughput and higher thermal efficiencies.

Step 7. **Optimize the energy supply**

Steps 5 and 6 will reduce your requirement for energy. Step 7 seeks the optimum source or sources for your overall energy requirement. This can include considerations such as heat recovery systems, alternative rate structures, alternative fuels, or even larger measures such as co-generation.

Continuous effort is required to maintain the energy savings after the projects are implemented. Thus, the ending of the energy savings process, Step 7, leads into the beginning of the next energy savings process, Step 1.

6 REFERENCES

6. REFERENCES

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APPENDICES

APPENDIX A. AREA DEFINITIONS

This appendix lists the definitions for the process areas in the pulp and paper mill.

Manufacturing areas

The manufacturing areas use energy and fibre resources to produce pulp and paper. The manufacturing areas are described below. The technology descriptors for the manufacturing areas are shown in Tables A-1 to A-3.

Table A-1 Technology descriptors–pulp manufacturing areas

Wood Preparation Area	• On-site, None
Kraft Pulping Areas	
Kraft Pulping	• Conventional batch, Displacement batch, Conventional continuous, MCC or EMCC, Lo-solids, Other (specify) • Oxygen delignification: Full oxygen delignification, Mini oxygen delignification, None
Kraft Evaporators	• Number of MEE effects • Concentrator type: Direct contact, Shell/tube integrated with MEE, Shell/tube not integrated with MEE, Other (specify) • Number of concentrator effects
Kraft Recausticizing	• Specify lime mud to kiln, percentage of solids
Sulphite Pulping Areas	
Sulphite Pulping	• Conventional batch, Displacement batch, Conventional continuous, MCC or EMCC, Lo-solids, Other (specify) • Oxygen delignification: Full oxygen delignification, Mini oxygen delignification, None
Sulphite Evaporators	• Number of MEE effects • Concentrator type: Direct contact, Shell/tube integrated with MEE, Shell/tube not integrated with MEE, Other (specify) • Number of concentrator effects
Sulphite Acid Plant	• Base: Sodium, Magnesium, Ammonium, Calcium • pH range: Acid sulphite, Bisulphite, Neutral, Alkaline
Mechanical Pulping Area	• Pulping Process: Stone groundwood (SGW), Pressurized groundwood (PGW), Refiner mechanical pulp (RMP), Thermomechanical pulp (TMP), Chemithermomechanical pulp (CTMP), Thermopulp or RTS, Other (specify) • Heat recovery: Primary refiners only, Mainline refiners only, Mainline and reject refiners, None
Recycled Pulping Area	• Recycled fibre used for newsprint, printing and writing paper, tissue, market DIP, board
Bleaching Areas	
Kraft Bleaching	• Specify bleaching sequence
Sulphite Bleaching	• Specify bleaching chemicals made on-site

Wood preparation area
Wood is received and prepared for pulping in the wood preparation area. The chip handling area produces screened chips and hog fuel from wood (or chips). The input boundary is the wood receiving facility. The output boundary is the inlet of the chip bin. The area includes chip piles and chip screening.

Kraft and sulphite pulping
The chemical pulping area produces brown stock pulp and black or spent sulphite liquor from wood chips and pulping liquor. The input boundaries are the inlet of the chip bin and the outlet of the pulping liquor storage tank. The output boundaries are the brown stock storage tank and the black or spent sulphite liquor tank. The area includes the digester, the brown stock washer, the screening and the brown stock decker.

The following equipment and processes can consume thermal energy:
- chip bin
- pre-steaming vessel
- indirect liquor heaters
- direct steam injection in the digester
- oxygen delignification reactor

Chemical pulping areas that use best practices would use thermal energy only in the digester liquor heaters and in oxygen delignification. The thermal energy for a chip bin and pre-steaming vessel would come from secondary heat.

Kraft and sulphite evaporators
The kraft and sulphite evaporators concentrate black liquor or spent sulphite liquor. The input boundary is the outlet of the black or spent sulphite liquor tank. The output boundary is the concentrated black or spent sulphite liquor tank. The area includes evaporators, concentrators and a soap skimmer.

Steam is used in both the multiple-effect evaporator train and the concentrators. It is also used in the ejectors. How much thermal energy is used depends on the number of evaporator effects. Steam economy for evaporator lines is calculated as steam divided by the water evaporated, measured in kilograms. According to best practices, the best steam economy is 0.8 times the number of effects.

Kraft recausticizing
The kraft recausticizing area produces white liquor from green liquor. The input boundary is the outlet of the smelt-dissolving tank in the recovery boiler area. The output boundary is the white liquor storage tank. The area includes the causticizer, green liquor clarifier, white liquor clarifier, lime mud filter and lime kiln.

The lime kiln uses fuel. Kraft recausticizing uses only a small amount of thermal energy. Possible users include green liquor heaters and mud filter water heaters. Best practices for thermal energy use in recausticizing is to not use steam during normal operation.

Sulphite acid plant

The sulphite acid plant produces pulping liquor from recovered chemicals and sulphur. The specific manner of chemical recovery depends on which sulphite process is used. For example, the choice of base affects the choice of chemical recovery.

The input boundary is the outlet of the smelt- or ash-dissolving tank in the recovery boiler (furnace) area. The output boundary is the pulping liquor storage tank. The area includes the liquor clarifier, sulphur burner and absorption tower.

Mechanical pulping area

The mechanical pulping area produces mechanical pulp (unbleached and bleached) from chips and electricity. It also produces steam if heat recovery is practised. The input boundary is the inlet of the chip bin. The outlet boundaries are the screened accepts chest and bleached pulp storage tank. The area includes chip steaming, impregnation, refining, screening and bleaching.

Mechanical pulping is the largest consumer of electricity of all the pulp processes. How much electricity is used is determined by the pulping technology, the wood species and the paper grade being manufactured.

For TMP, thermal energy can be used by chip pre-treatment and the pre-steaming bins. TMP lines that use best practices use refiner steam for thermal demands and use a reboiler to recover heat from refiner steam to produce clean steam for use in other manufacturing areas.

Recycled pulping area

The recycled pulping area produces recycled pulp from waste paper. The input boundary is the waste paper storage. The outlet boundary is the recycled pulp storage tank. The area includes pulping, flotation, screening, bleaching and dispersion.

Thermal energy can be consumed for pulping, dispersion and bleaching. How much thermal energy is used for pulping depends on how much fresh water is used and whether the mill is integrated. Integrated mills that use best practices use no thermal energy for pulping, because the required heat comes from the paper machine whitewater.

Kraft and sulphite bleaching

The kraft and sulphite bleaching area produces bleached pulp from brown stock pulp. The input boundary is the outlet of the brown stock storage tank. The output boundary is the bleached stock storage tank. The area includes oxygen delignification, the bleaching stages and washers, and bleaching chemical preparation.

The following equipment uses thermal energy:

- bleach plant stock steam mixer
- water heater
- bleach plant scrubbers
- chlorine dioxide generator reboiler
- chlorine dioxide generator ejectors

Mills that use best practices use secondary heat for heating water instead of using steam.

Table A-2 Technology descriptors–product manufacturing areas

Paper Machines Newsprint Uncoated Groundwood Specialties Printing and Writing Papers Kraft Papers Tissue and Specialty Papers Building Paper	• Wet end: Cylinder former, Fourdrinier, Twin-wire, Other (specify) • Dry end: Steam cylinders, Air flotation, Yankee dryer, Through-air dryer, Other (specify) • Calendering: On-line, Off-line, None • Coating: On-line, Off-line, None
Board Machines Linerboard Corrugating Medium Boxboard Hardboard Building Board	• Wet end: Cylinder former, Fourdrinier, Twin-wire, Other (specify) • Dry end: Steam cylinders, Air flotation, Yankee dryer, Through-air dryer, Other (specify) • Calendering: On-line, Off-line, None • Coating: On-line, Off-line, None
Pulp Machines Kraft Pulp Sulphite Pulp Mechanical Pulp Recycled Pulp	• Pulp type: Wet lap, Dried pulp • Wet end: Cylinder former, Fourdrinier, Twin-wire, Other (specify), None • Dry end or dryer: Rod and chain, Air flotation, Steam cylinders, Yankee dryer, Through-air dryer, Flash dryer, Other (specify), None
Off-Line Operations Off-Line Calender Off-Line Coater Converting Operation	No technology descriptors

Paper and board machines
The paper machine area produces finished paper from chemical, mechanical and recycled pulps. Similarly, the board machine area produces board.

The input boundaries are the
- outlet of the bleached stock storage tank (chemical pulp)
- outlet of the screened accepts chest and bleached storage tank (mechanical pulp)
- outlet of the recycled pulp storage tank

The output boundary is the paper warehouse. For mills that have off-line finishing operations, the output boundary is the paper machine reel.

Paper and board machines use thermal energy mainly for drying paper. Some thermal energy is used for warm water heating, steam showers, silo whitewater heating and calender heating.

Paper machines that use best practices have high-humidity dryer hoods, stationary siphons and use only a small amount of fresh water. Heat recovered from the dryer exhaust air is used to preheat incoming dryer air and to meet some of the demands for warm water and whitewater heating.

Fuel is used to dry coatings in infrared dryers.

Pulp machines
The pulp machine area produces finished market pulp from bleached pulp. The input boundary is the outlet of the bleached stock storage tank. The output boundary is the pulp warehouse. The area includes the pulp machine, pulp dryer and pulp finishing.

Pulp machines with steam cylinders or air flotation dryers use thermal energy mainly for paper drying. Some thermal energy may be used for warm water heating, steam showers and silo whitewater heating. Fuel is used to dry pulp in flash dryers.

Off-line operations
For some mills, the product is not finished on the paper machine but on an off-line calender or coater. Some mills also have converting operations, such as cutting paper rolls into sheets. The input boundary is the paper machine reel. The output boundary is the pulp warehouse.

Table A-3 Technology descriptors–common areas

Water Treatment	No technology descriptor
Effluent Treatment	• Treatment for discharge: Activated sludge, Aerated lagoon, Anaerobic treatment, Other (specify) • Treatment for water recycle • Evaporation, Other (specify), None
General/Buildings	No technology descriptor

Water treatment

The water treatment area produces treated effluent and sludge from mill effluent. The input boundary is the raw water supply. The output boundary is the mill water supply header. The area includes clarification and filtration.

Effluent treatment

The effluent treatment area produces treated effluent and sludge from mill effluent. The input boundaries are the sewers leaving the other mill areas. The output boundaries are the treated effluent outfall and the sludge storage bin. The area includes primary clarification, secondary treatment and sludge dewatering.

Thermal energy may be used for steam stripping of foul condensates. Biological treatment of mill effluent typically does not use thermal energy.

General and buildings

The office and miscellaneous area includes all energy uses not assigned to other areas. The area includes offices and maintenance facilities.

Energy conversion areas

The energy conversion areas convert purchased and self-generated energy to steam and electricity for use in the manufacturing areas or for sale. The energy conversion areas are described below. The technology descriptors for the energy conversion areas are shown in Table A-4.

Table A-4 Technology descriptors–energy conversion areas

Steam Generation Areas	
Power Boiler	• Grate type, Fluidized bed, Package boiler, Other (specify)
Recovery Boiler	• Direct contact, Low odour, Other (specify) • Specify fired black liquor, percentage of solids
Deaerator	No technology descriptor
Power Generation Areas	No technology descriptors
Gas Turbine – Electricity	
Gas Turbine – Mechanical Energy	
Back-Pressure Turbine – Electricity	
Back-Pressure Turbine – Mechanical Energy	
Condensing Turbine – Electricity	
Condensing Turbine – Mechanical Energy	
Fuel Cells – Electricity	
Reciprocating Engine (gas/diesel) – Electricity	
Reciprocating Engine (gas/diesel) – Mechanical Energy	

Power boiler
The power boiler produces steam and ash from fossil fuel and bio-fuels (hog fuel, sludge). The input boundaries are the
- receiving facilities for purchased fuel
- hog fuel pile
- sludge storage bin

The output boundaries are the steam header and ash-to-landfill. The area includes fuel handling, boilers and ash handling.

Air heaters and soot blowers can use thermal energy. Thermal energy use is relative to the size of the boiler; smaller boilers do not use thermal energy.

Kraft recovery boiler
The kraft recovery boiler produces steam and green liquor from concentrated black liquor. The input boundary is the outlet of the concentrated black liquor tank. The output boundary is the steam header and smelt-dissolving tank. The area includes the recovery boiler, precipitator and smelt-dissolving tank.

Thermal energy is consumed by
- soot blowers
- air heaters
- fired black liquor heater
- smelt shatter jets
- steam drives on boiler fans or the feed water pump

Recovery boilers that use best practices use 5 percent of the steam generation for soot blowing.

Sulphite recovery boiler (furnace)
The sulphite recovery boiler (or furnace) produces steam, smelt or ash, and flue gas from concentrated spent sulphite liquor. The specific manner of incineration depends on the sulphite process employed. For example, the choice of base affects the choice of incineration method. The input boundary is the outlet of the concentrated spent sulphite liquor tank. The outlet boundary is the steam header and the smelt- or ash-dissolving tank. The area includes the recovery boiler (furnace), precipitator and dissolving tank.

Deaerator
The deaerator produces boiler feed water from condensate, water make-up and steam. The thermal energy consumption depends on the amount of overall condensate return as well as on the use of secondary heat to preheat the make-up boiler feed water and/or the returned condensate before they enter the deaerator.

Power generation areas
In the power generation areas, fuel and steam are used to produce electricity and mechanical energy.

Fuel is used by gas turbines, fuel cells and reciprocating engines. The input boundary for these areas is the fuel supply (for example, gas main, oil tank). The output boundary is the produced electricity or mechanical energy.

Steam is used by back-pressure and condensing turbines. The input boundary for these steam turbines is the steam header. The output boundary is the produced electricity or mechanical energy. The exhaust steam from the back-pressure turbine is recovered and used in the process. The exhaust steam from the condensing turbine is condensed.

APPENDIX B. SAMPLE CALCULATION

This section shows sample calculations for a pulp and paper mill that produces newsprint from thermomechanical pulp (TMP). The energy use is determined following the methodology described in Section 2. First, the mill is divided into process areas. Then, energy data is collected, allocated to process areas and reconciled. Finally, the specific energy values are calculated for each process area.

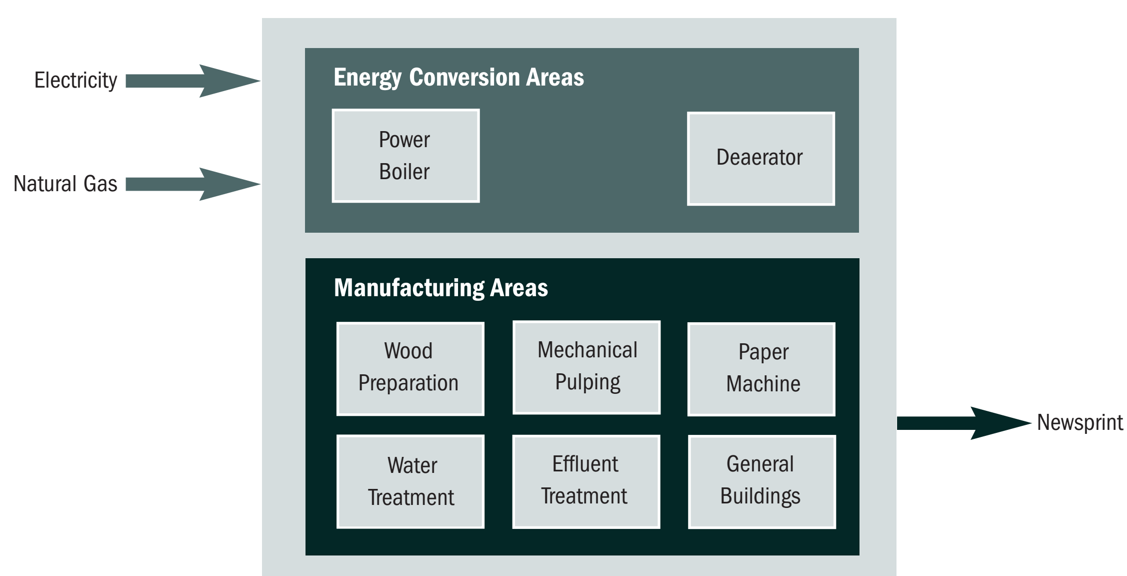
A diagram of a pulp and paper mill that produces newsprint from TMP is shown in Figure B-1.

The mill is divided into several areas for energy conversion and pulp and paper manufacturing.

In the energy conversion areas, purchased fuel is converted to steam for use in the manufacturing areas. The energy conversion areas include the power boiler and deaerator.

In the manufacturing areas, energy resources (fuel, steam and electricity) and fibre resources are used to produce newsprint. The manufacturing areas include
- wood preparation
- mechanical pulping
- paper machine
- water treatment
- effluent treatment
- general areas (for example, buildings)

Figure B-1 Energy conversion and manufacturing areas of a mill producing newsprint from TMP



The raw data, reconciled data and specific energies for a mill that produces newsprint are shown in Tables B-1 to B-3.

In Table B-1, along with the energy and fibre data, the quality of the data (A, B, C or D) is reported:

- A–reliable instrumentation with good calibration
- B–less reliable instrumentation
- C–calculated by heat and material balance from measured values
- D–estimated when measurements unavailable

The actual fibre productions are given for the wood preparation, mechanical pulping and paper machine areas. The total mill production is used to calculate the specific energies for the remaining areas.

The purchased energies (electricity and natural gas) are energy inputs in Table B-1. The data quality for these energy inputs is A because they are measured with reliable instrumentation with good calibration.

The data qualities for the energy produced and consumed by the manufacturing and energy conversion areas range from A to D.

The total energy supply is the sum of the energy inputs and energy produced by the areas. The total energy demand is the sum of the energy consumed by the areas. The total energy supply is not equal to the total energy demand for electricity, steam and condensate because of instrument measurement errors and estimates being used when measurements are unavailable.

Table B-1 Energy data for a newsprint mill

	Electricity (GWh)	Fuel (TJ)	Steam (TJ)	Condensate (TJ)	Fibre Produced or Allocated	
Inputs						
Electricity	119.85 A				Total Production (ADt)	39 326
Natural Gas		206.31 A			Total Production (ADt)	39 326
Produced						
Power Boiler			184.17 A		Total Production (ADt)	39 326
Deaerator				54.57 C	Total Production (ADt)	39 326
Wood Preparation					Chips (ODt)	40 956
Mechanical Pulping			157.70 A	5.15 B	TMP (ODt)	39 907
Paper Machine				32.27 B	Newsprint (ADt)	39 326
Effluent Treatment					Total Production (ADt)	39 326
Water Treatment					Total Production (ADt)	39 326
General/Buildings				3.72 B	Total Production (ADt)	39 326
Total Energy Supply	119.85	206.31	341.87	95.71	Total Production (ADt)	39 326
Consumed						
Power Boiler		205.60 A	17.73 B	28.16 C	Total Production (ADt)	39 326
Deaerator			23.50 B	41.14 B	Total Production (ADt)	39 326
Wood Preparation	0.55 B				Chips (ODt)	40 956
Mechanical Pulping	94.98 B		6.13 A	25.17 B	TMP (ODt)	39 907
Paper Machine	21.77 B		264.43 A		Newsprint (ADt)	39 326
Effluent Treatment	4.05 B				Total Production (ADt)	39 326
Water Treatment	0.29 D				Total Production (ADt)	39 326
General/Buildings	3.60 C	0.71 B	22.57 A		Total Production (ADt)	39 326
Total Energy Demand	125.24	206.31	334.34	94.47	Total Production (ADt)	39 326
Difference	– 5.39	0.00	7.52	1.24		
% Difference	– 4.50	0.00	2.20	1.30		

The quality of the data is used to weight the corrections needed to reconcile the energy data in Table B-2. The energy value does not change for A-quality data. The percentage change in the energy value is weighted by 1 for B-quality data, by 2 for C-quality data and by 4 for D-quality data.

For example, for electricity in Table B-2, the value for purchased electricity does not change because its data is A-quality.

The data quality for wood preparation, mechanical pulping, paper machine and effluent treatment is B-quality. Therefore, its value is reduced by a weighted factor of 4.2 percent.

The data quality for general and buildings is C. Its value is reduced by 8.4 percent (2 times 4.2 percent).

The data quality for water treatment is D. Its value is reduced by 16.8 percent (4 times 4.2 percent).

Similar changes are made for steam and condensate data. No changes were made to the fuel values.

Table B-2 Reconciled energy data for a newsprint mill

	Electricity (GWh)	Fuel (TJ)	Steam (TJ)	Condensate (TJ)	Fibre Produced or Allocated	
Inputs						
Electricity	119.85				Total Production (ADt)	39 326
Natural Gas		206.31			Total Production (ADt)	39 326
Produced						
Power Boiler			184.17		Total Production (ADt)	39 326
Deaerator				54.07	Total Production (ADt)	39 326
Wood Preparation					Chips (ODt)	40 956
Mechanical Pulping			157.70	5.13	TMP (ODt)	39 907
Paper Machine				32.12	Newsprint (ADt)	39 326
Effluent Treatment					Total Production (ADt)	39 326
Water Treatment					Total Production (ADt)	39 326
General/Buildings				3.71	Total Production (ADt)	39 326
Total Energy Supply	119.85	206.31	341.87	95.03	Total Production (ADt)	39 326
Consumed						
Power Boiler		205.60	20.96	28.41	Total Production (ADt)	39 326
Deaerator			27.79	41.33	Total Production (ADt)	39 326
Wood Preparation	0.53				Chips (ODt)	40 956
Mechanical Pulping	91.03		6.13	25.29	TMP (ODt)	39 907
Paper Machine	20.86		264.43		Newsprint (ADt)	39 326
Effluent Treatment	3.88				Total Production (ADt)	39 326
Water Treatment	0.24				Total Production (ADt)	39 326
General/Buildings	3.30	0.71	22.57		Total Production (ADt)	39 326
Total Energy Demand	119.85	206.31	341.87	95.03	Total Production (ADt)	39 326
Difference	0.00	0.00	0.00	0.00		

The specific energies are shown in Tables B-3 and B-4. The specific energy for each area was calculated by using the reconciled data in Table B-2.

The thermal energy consumed is equal to the steam consumed by the area minus the condensate returned to the boilers.

The thermal energy produced by the boiler is equal to the steam produced minus the condensate (boiler feedwater) consumed.

The deaerator produces boiler feedwater from condensate, water make-up and steam. Its thermal energy produced is equal to the boiler feedwater produced minus the condensate and steam consumed. Its value of 0.67 GJ/t represents the enthalpy of the water make-up minus heat losses.

The energy consumption for the power boiler is expressed in terms of the thermal energy produced by the boiler in Table B-2.

Table B-3 Specific energy data for a newsprint mill

	Electricity (kWh/t)	Fuel (GJ/t)	Steam (GJ/t)	Fibre Produced or Allocated	
Inputs					
Electricity	3 047.51			Total Production (ADt)	39 326
Natural Gas		5.25		Total Production (ADt)	39 326
Produced					
Power Boiler			3.96	Total Production (ADt)	39 326
Deaerator			0.67	Total Production (ADt)	39 326
Wood Preparation				Chips (ODt)	40 956
Mechanical Pulping			3.32	TMP (ODt)	39 907
Paper Machine				Newsprint (ADt)	39 326
Effluent Treatment				Total Production (ADt)	39 326
Water Treatment				Total Production (ADt)	39 326
General/Buildings				Total Production (ADt)	39 326
Consumed					
Power Boiler		5.23	0.53	Total Production (ADt)	39 326
Deaerator				Total Production (ADt)	39 326
Wood Preparation	12.94			Chips (ODt)	40 956
Mechanical Pulping	2 280.97		0.02	TMP (ODt)	39 907
Paper Machine	530.56		5.91	Newsprint (ADt)	39 326
Effluent Treatment	98.78			Total Production (ADt)	39 326
Water Treatment	6.11			Total Production (ADt)	39 326
General/Buildings	83.88	0.02	0.48	Total Production (ADt)	39 326

Table B-4 Energy consumption of the power boiler

Electricity Consumption (kWh/GJ)†	Fuel Consumption (GJ/GJ)†	Thermal Energy Consumption (GJ/GJ)†
0.00	1.32	0.13

† The specific energy is the energy consumed divided by the thermal energy produced.

APPENDIX C. PAPRICAN ENERGY BENCHMARKING SURVEY INSTRUCTIONS

This appendix describes the survey worksheets and data codes, and explains how to enter the data into the worksheets to complete the Energy Benchmarking survey.

Survey worksheets

The Excel workbook for the Energy Benchmarking survey contains the following worksheets:

1. **Process Description –** Use this worksheet to specify the mill's inputs (i.e. energy), outputs (i.e. fibre) and process areas.

2. **Technology Descriptors –** Use this worksheet to enter the technology descriptors of the process areas as defined in the Process Description worksheet.

3. **Data –** Use this worksheet to enter the energy and fibre amounts for the mill's inputs, produced outputs, and process areas.

4. **Reconciled Data –** This worksheet displays the reconciled data based on the information provided in the first three worksheets.

5. **Specific Energy –** This worksheet calculates and displays specific energies using data from the Reconciled Data worksheet.

6. **Summary –** This worksheet displays the energy balance for the mill.

You will enter data in the first three worksheets – Process Description, Technology Descriptors and Data. In turn, the data you entered will populate the latter three worksheets – Reconciled Data, Specific Energy and Summary, providing you with the survey results.

1. Process Description worksheet

The Process Description worksheet contains two sections:
- Inputs and Outputs
- Process Areas

Each section contains a series of codes that pertain to a mill's activities as shown in the following subsections.

1.1 Inputs and outputs

Under the Inputs and Outputs section of the worksheet, enter the types of pulp and paper the mill produces and its energy inputs and outputs as described below.

Codes A.1 to A.15	Pulp and Paper Production • For each product type produced by the mill, click the corresponding cell in column C; from the drop-down menu, select Yes.
Codes A.16 to A.19	Purchased Pulp • For each pulp type purchased by the mill, click the corresponding cell in column C; from the drop-down menu, select Yes.
Codes B.1 to B.18	Purchased Energy • For each energy type purchased by the mill, click the corresponding cell in column C; from the drop-down menu, select Yes.
Codes B.20 to B.25	Self-Generated Energy • Self-generated energy consists of biofuels generated in the mill (e.g. spent pulping liquor and hydraulic energy). It does not include steam and power produced in the energy conversion areas. • For each energy type that is self-generated by the mill, click the corresponding cell in column C; from the drop-down menu, select Yes. • If spent pulping liquor (Code B.22) is self-generated, click the corresponding cell in column D; from the drop-down menu, select the chemical pulping type used by the mill.
Codes B.27 and B.28	Sold Energy • For each energy type sold by the mill, click the corresponding cell in column C; from the drop-down menu, select Yes.

1.2 Process Areas

Under the Process Areas section of the worksheet, enter information into each of the four areas as described below.

Codes C.1 to C.25 Energy Conversion Areas

- In column B, click the first cell; from the drop-down menu, select one type of energy conversion area used by the mill.
- Repeat previous step for each energy conversion type or area used by the mill.
- For each entry made in column B, select the corresponding cell in column C and type the name of the area.

Codes D.1 to D.25 Pulping Process Areas

- Select the type of pulping process area from the list in the drop-down menu in the corresponding yellow cells in column B.
- Input the area name in the corresponding yellow cells in column D.
- Select the fibre produced or allocated (wood, pulp) from the drop down menu in the corresponding yellow cells in column D.
- Some areas, such as kraft evaporators, do not produce fibre products. The product for these areas is the fibre product associated with their operation. Therefore the product for kraft evaporators is the unbleached kraft pulping produced in making black liquor.

Codes E.1 to E.25 Finishing Process Areas

- Select the type of finishing process area from the drop-down menu in the corresponding yellow cells in column B.
- Input the area name from the drop-down menu in the corresponding yellow cells in column C.
- Select the fibre produced or allocated (paper, board, pulp) from the drop-down menu in the corresponding yellow cells in column D.

Codes F.1 to F.25 Common Process Areas

- Select the type of common process area from the drop-down menu in the corresponding yellow cells in column B.
- Input the area name from the drop-down menu in the corresponding yellow cells in column C.

2. Technology Descriptors worksheet

The Technology Descriptors worksheet contains the technology descriptors for each of the mill's energy conversion areas and process areas. These areas are identified by their code, type and name (see columns A to C) as previously defined in the Process Description worksheet. The technology descriptor types are listed in the worksheet in columns D, F, H and J alongside codes C.1 to F.25.

For each technology descriptor type listed in columns D, F, H and J, click the corresponding yellow cell in columns E, G, H and I and select a technology descriptor entry from the drop-down menu or enter the requested value. If you select option Other (specify), specify a value.

3. Data worksheet

The Data worksheet contains the energy and fibre data and is subdivided into two sections:

- Data – Inputs and Produced
- Data – Inputs and Consumed

The inputs, outputs and process areas are identified by their code, type and name (see columns A to C) as previously defined in the Process Description worksheet. Process areas that produce and consume energy will have data in both sections.

Enter the reporting period in row 2 of this worksheet as follows:

- click cell E2; from the drop-down menu, select the quarter
- click cell F2; from the drop-down menu, select the year

Then, enter data in each section of the worksheet: Data – Inputs and Produced (see row 2) and Data – Outputs and Consumed (see row 149) as described below.

3.1 Data – Inputs and Produced

The energy and fibre types listed in the Data – Inputs and Produced section of the worksheet (codes A.16 to F.25) match those specified in the Process Description worksheet.

In each of the yellow-highlighted cells, enter the energy or fibre value. For each entry with a drop-down menu, select the data quality. Also, enter the following information:

- in columns D to K, enter energy data
- in columns L to BS, enter fibre data
- in columns BT to CA, enter purchased fibre
- in columns CB to CM, enter allocated fibre

The chemical pulp evaporators, recovery boiler and recausticizing areas do not produce fibre products. The value of allocated fibre for these areas is the unbleached chemical pulp production that is associated with the processed spent pulping liquor.

3.2 Data – Outputs and Consumed

Complete the Data – Outputs and Consumed section of the worksheet (codes A.1 to F.25) as follows:

- in columns D to K, enter energy data
- in columns L to BS, enter fibre data
- in columns BT to CA, enter purchased fibre
- in columns CB to CM, enter allocated fibre

4. Reconciled Data worksheet

The Reconciled Data worksheet displays the reconciled data. No data entry is required for this worksheet.

5. Specific Energy worksheet

The Specific Energy worksheet calculates and displays the specific energies using the reconciled data from the Reconciled Data worksheet. No data entry is required for this worksheet.

6. Summary worksheet

The Summary worksheet displays the energy balance for the mill.

DISCLAIMER

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