PULP AND PAPER INDUS TRY ENERGY BANDWIDTH STUDY

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ABSTRACT

A pulp and paper industry energy bandwidth study was conducted with support from the AIChE and DOE-OIT. The objective was to use results of this study to identify the R&D areas that have the greatest potential for energy savings. To accomplish this result, the following estimates were made:

- An estimate of the current average energy consumption by mill areas / technologies based on the 2002 Manufacturing Energy Consumption Survey (MECS)
- An estimate of what the energy consumption would be by mill areas / technologies if "Best Available" practices were applied utilizing current state-of-the-art (SOA) or Best Available Technologies (BAT).
- An estimate in selected mill areas / technologies of what the energy consumption would be if new technologies could be developed to drive energy consumption down to "practical minimum" using advanced technology not currently practiced. The difference between today's average and the "practical minimal technologies" represents an area of opportunity that could be used to direct research grant money to encourage the development of technologies that would result in reduced energy consumption
- An estimate of what the energy consumption would be of selected mill areas / technologies if " theoretical minimum" energy (based on theoretical calculations) could be achieved.

INTRODUCTION

In 2000 the U.S. Paper Industry produced 105.6 million tons of pulp and paper products while consuming 2,361 trillion Btus of thermal and electrical energy. The 2002 Manufacturing Energy Consumption Survey (MECS) data was used for an estimate of current average energy consumption since these are the latest government published numbers and these consumption figures match published production data for the same time period. Since 2000, the Pulp and Paper Industry has reduced it's energy consumption, primarily through the use of waste energy streams - capturing the energy in waste heat streams, both air and liquid, and using energy saving devices such as variable speed motors and more efficient lighting. The relative difference between actual and projected energy savings was determined for each of two cases: use of Best Available Technology (BAT) and use of advanced technologies (Practical Minimums).

This study is production weighted. The energy consumed is based on the tons of pulp and paper produced by type (kraft, thermo-mechanical pulp (TMP), printing & writing, linerboard, etc.) multiplied by the energy consumed per ton for the various large process areas within a mill. Examples of large process areas are: pulping, bleaching, liquor evaporation, stock preparation, and paper drying. Though TMP consumes a large quantity of electric power per unit of pulp produced, total energy consumed is small compared to the energy consumed by the U.S. pulp and paper industry since only a small quantity of TMP is produced in the U.S. This study focuses on the large blocks of energy consumed by the U.S. pulp and paper industry rather than the large process units with relative little impact on the industry's total energy consumption.

PAPER INDUSTRY ENERGY CONSUMPTION

MECS tables served as the basis for the paper industry energy consumption in this bandwidth study. The United States paper industry (NAICS Code 322) used approximately 2,361 trillion Btus (TBtu) while producing approximately 105.6 million tons of pulp and paper products in 2000 (Table I) [1-3]. The largest category of fuel used by the industry is black liquor and hog fuel (bark / wood waste), which represent about 54.3% of the industry's energy input. These fuel categories are included in the MECS classification as "Coke and Other", which are largely byproduct fuels used as fuel and for on-site electrical generation (Table II). (Black liquor represents 71% of the 'other' category and hog fuel 27%.) Natural gas is the second largest category at 21.3%, with coal and net (purchased) electricity at 9.9% and 9.4%, respectively. "Net Electricity" totals 223 TBtu (65,339 million kWh), and is obtained by summing the purchases, transfers in and generation from noncombustible renewable resources, minus quantities sold and transferred out. It does not include electricity inputs from onsite co-generation or generation of combustibles fuels because that energy has already been included in generating fuel (e.g. coal, hog or black liquor). On-site generation has been taken into account separately and is 51,208 million kWh (44% of its total electrical requirements) (Table III).

Cross check of the DOE MECS numbers against energy consumption figures reported by American Forest and Paper Association (AF&PA) in the 2002 Statistics Report (Table IV) indicated close agreement (difference of about 8%) [4]. Neither database covers the complete paper industry, and the accuracy of the data is dependent upon the effort the reporting companies invested in collecting the data. The MECS is based on companies that responded to the survey. AF&PA data is generally limited to AF&PA member companies, although some non-member companies have given AF&PA information, and not all member companies provide information to AF&PA. In addition, the AF&PA and MECS numbers were checked against Paperloop's (now RISI) Analytical Cornerstone® database which reports purchased energy consumed by the paper industry [5]. The check did not identify any significant differences and validated the AF&PA and MECS purchased energy numbers.

PAPER INDUSTRY PRODUCTION

AF&PA 2002 Statistics data (which reported the revised production data for the year 2000) are the basis for the production figures used in the current bandwidth study. The AF&PA production figures were compared against Fisher International's database [6]. The check did not identify any significant differences.

In 2000, paper and board production was 94.5 million tons and market pulp production was 11.1 million tons (Table V). Note that all tonnage units reported are short tons unless otherwise indicated. The largest category of paper products was board (52%), followed by printing and writing paper (22%), mechanical paper grades (14%) and tissue products (7%) (Figure 1. For the same period, pulp production was 92 million tons (Table VI). Kraft pulp accounted for 56% of the total pulp production in the U.S. (Figure 2). The largest category was bleached kraft (33%), followed by unbleached kraft (23%). Recycled fiber accounted for 32% of the total pulp with old corrugated containers (OCC) being 62% of the total recycle fiber (Table VI).

PAPER INDUSTRY AVERAGE PROCESS ENERGY DEMAND IN PULPING AND PAPERMAKING

To relate the MECS energy numbers and the AF&PA production (shipment) data, as a starting point consumption figures (units per ton) were used as available from available published databases. Comparison of the various databases shows that there are wide variations in the reported amount of energy used by different pulping processes and by the individual process steps. The same goes for the paper manufacturing energy information. The large differences between the databases and the published information are in part due to the large number of manufacturing variables, including age of equipment, mill / system configuration, and mill reporting systems- e.g., not all mills have the same accounting systems or mill system classifications; metering systems are in many cases missing; data is in some cases assumed based on other mill operations, leading to potentially incorrect results. Therefore, using an average number based on the various databases minimizes the impact of the use of incorrect information.

The first step was to determine how much of the fuel consumed by the paper industry was actually available for manufacturing processes. To do this, determination was made of the amount of non-process fuel consumed in the powerhouse based on boiler efficiencies and energy estimates for auxiliary systems (fans, pumps, coal crushers, bark hog, turbine loses, transformer losses, environmental systems, etc.) and other losses such as leaks and venting. Subsequently, based on a simple analysis it was estimated that approximately 69% (1,623 TBtu) of the 2,361 Trillion Btu (TBtu) reported in MECS (Table 3.2) is available for paper industry manufacturing processes (Table VII).

The second step was to distribute the energy consumed among the various pulp and paper making processes. Published data referencing energy consumption per ton was used and indicated a wide range of energy consumption for the same unit operation and/or paper grade. An initial estimate was made based on consumption numbers obtained from Paprican's book "Energy Cost Reduction in the Pulp and Paper Industry" and AF&PA reported production numbers [7,8]. Unit consumption figures were adjusted so the total energy consumption matched the energy available for process after the powerhouse.

The third step was to distribute the energy into smaller energy process blocks. We utilized the available published data and adjusted the data based on our knowledge of the industry. To minimize errors, we elected to use as large a database of published information as we could find to generate an average since the published data for the same processes vary [7-16].

The energy use within U.S. Pulp and Paper Industry manufacturing (pulp and paper products) was broken down into three use categories: Electric, Steam and Direct Fuel. Using the electrical, steam and direct fuel energy consumption data by pulping and paper grade, along with production data (Tables V and VI), total domestic energy consumption was obtained (Tables VIII and IX). Kraft pulping, bleached and unbleached, accounts for 76% of the total energy consumed by pulping (Figure 3). Pulping process energy use per ton is shown in Figure 4. Distributions of total energy for paper manufacturing by product are shown in Figures 5 and 6

Overall average break-down of the energy used within pulp and paper manufacturing was determined to identify areas of future emphasis for energy savings. Steam energy use indicates evaporation as the largest energy user within pulp manufacturing and drying as the largest within papermaking (Tables X and XI). This is also shown in Figure 7 representing the energy consumption of a typical bleached hardwood kraft mill along with a printing and writing paper machine. Grinding/ refining – type operations consume the largest amounts of electricity within both pulping and papermaking (Tables X and XI). In pulp manufacturing 100% of the direct fuel is used in either the lime kilns (kraft pulping – 98.4%) or sulfur burners (sulfite pulping – 1.6%); in paper manufacturing 100% of the direct fuel is used either for coating drying (51%) and/or tissue drying (Yankee hoods and/or Through Air Drying (TAD) – 49%).

OVERALL DOMESTIC ENERGY BALANCE

Combining the consumption data (Table VIII) and the generation data (Table VII) allows the overall domestic energy balance to be calculated (Table XII). There is good agreement between the net mill demand and the MECS Industry Demand (Table XII). The 4.5 TBtu (223 TBtu – 218.5 TBtu) difference in purchase electricity, due to 2% system loses, shown in Table VII is equivalent to the 1,307 Million kWh shown above as powerhouse demand.

ESTIMATED CONSUMPTION WITH "BAT"

The estimated energy consumption using BAT was based on MECS / AF&PA production data along with published data for either modern and/or model mills [17-21]. Published information was used because modern design data related to new mills is limited. The last new domestic greenfield pulp mill was built in the early 1980's. (Recent construction of new mills has occurred in Asia and South America.) In some cases, such as sulfite pulping, there isn't any data that represents a current mill design since that pulping technology, for the most part, is being phased out. In cases like sulfite, the energy data used for the MECS distribution is reused.

To determine BAT energy consumption, the methodology used in the MECS distribution remained the same - using the electrical, steam and direct fuel energy consumption data by pulping and paper grade, along with production data (Tables V and VI). The BAT distribution was used to predict fuel use by back calculating through the powerhouse, first generating Table XIII and then back calculating Table XIV. The efficiencies used in the powerhouse are the best rather than the average. Since pulp production has been maintained, the amount of energy available from hog fuel and black liquor has been maintained (Table VII) causing other quantities available from other energy sources to float. Powerhouse energy efficiencies were raised and energy generated from hog fuel and black liquor remained constant since production remained constant from MECS.

The analysis showed that current design technology in the papermaking and pulping processes could reduce energy consumption by 25%, from 1,623 TBtu to 1,217 TBtu. Tables XIII and XV summarize the changes. Energy distribution and use within the pulp and papermaking processes was determined after applying BAT. Applying BAT reduces purchased fuels, excluding electricity, to 518 TBtu (Table XIV). BAT is a combination of new technologies, such as shoe presses, and improved capture and reuse of energy contained in "waste" process streams, such as paper machine dryer hoods and bleach plant effluents.

It is noted that both MECS and BAT are based on energy consumption, which incorporates recovered heat integration. There are many interrelationships between process areas, like between digesting / washing and evaporation that impact energy use. Energy heat recovery is just one of many relationships impacting gross energy consumption. Today's' energy efficient mills do recover "waste" heat energy.

ENERGY CONSUMPTION: COMPARISON OF CURRENT AVERAGE VERSUS USE OF "BAT"

The major energy users within the U.S. pulp and paper industry include the areas of paper drying, liquor evaporation, and the pulp mill chemical prep area including the lime kiln (Table XVI, Figure 8). The distribution of energy used, based on MECS in the pulp and paper industry is shown in Table XVII [1, 2]. The energy consumed in the powerhouse is the energy that is used within the powerhouse due to boiler efficiency, soot blowing, steam venting, and turbine and transformer efficiency, and is not the energy that exits the powerhouse to be used in the manufacturing processes.

By applying BAT – current design practices for the most modern mills - energy consumption within the Pulp and Paper Industry can be improved by 22.9% for an annual use estimate of 1,821 TBtu vs. the MECS data of 2,361 TBtu (Table XVII). Purchased energy, excluding electric power, can be reduced from 886 TBtu (MECS case) to 517 TBtu (BAT Case), a 41.7% reduction. BAT calculations were based on the MECS energy distribution matrix. Published design unit energy consumptions for new or modern mill designs (vs. MECS unit consumption being "average" for 90 vintage mills) were used to back calculate energy consumption.

The energy use for manufacturing pulp and paper by type (direct fuel, electricity and steam) is shown in Table XVIII. Powerhouse loses in co-generation of the steam and electricity needed for the manufacturing processes account for the remaining energy consumed in the industry. Energy use by type within the pulp and paper manufacturing, after applying BAT, is also shown in Table XVIII.

The six major consumers by area within Pulp and Paper manufacturing are shown in Table XIX

ENERGY CONSUMPTION – PRACTICAL AND THEORETICAL MINIMUM REQUIREMENTS

Areas of Opportunity

The major energy users within the U.S. pulp and paper industry include the areas of paper drying, liquor evaporation, and the pulp mill chemical prep area including the lime kiln (Table XVI, Figure 8). Potential energy savings (bandwidth) between BAT and Practical Minimum are:

- Paper Drying – 66%
- Liquor Evaporation – 27%
- Lime Kiln – 35%

Paper Drying

Modern press sections including a shoe press have exit moistures typically ranging from 42 to 50%. Average drying requirements were estimated at 4.20 MM Btu/finished short ton (fst) and BAT at 3.8 MMBtu/fst (Figures 7). Calculation of practical minimum energy consumption in drying of 1.3 MM Btu/fst was based on press section dewatering to 65% solids followed by drying of the remaining water at a steam usage of 1.3 lbs steam per lb water evaporated [22]. The 65% exiting press solids is based on previous laboratory work indicating achievement of exiting solids around that level under certain optimized pressing conditions [23].

Water removal by pressing is ultimately limited to about 70%, due to the amount of water contained within the fiber cell itself. Based on exiting solids of 70%, the theoretical dryer energy required was calculated to be 0.88 MMBtu/fst [24]. This calculation is based on energy required to heat the water and fiber, to evaporate the water, and to desorb the water. If the solids were raised to 70%, then the potential energy reduction for drying is 79%. Figure 9 shows the theoretical minimum drying energy required at various exiting press solids. The summary chart showing average, BAT, Practical Minimum, and Theoretical Minimum drying energy required is shown in Figure 10.

Lime Kiln

A modern BAT kiln based on lime kiln manufactures' design data requires about 5.0 MMBtu/st lime (approximately 1.34 MMBtu/adst of pulp assuming 480 lbs of active CaO used per ton pulp in the causticizer[25]). Electrical energy adds an estimated 0.04 MMBtu/adst (forced draft (FD) and induced draft (ID) fans, electrostatic precipitators (ESP), vacuum pumps and the kiln drive plus smaller pumps and conveyors). Jaakko Pöyry reported that some mills are using about 1.15 GJ/adt (1.0 MMBtu/adst) fuel in their kilns [26]. Mills producing tropical hardwoods, with oxygen delignification, higher yields and lower alkali charges can achieve low kiln fuel use on a pulp ton basis. Current commercial designs generally use either an external mud dryer or an efficient chain section to utilize waste (flue gas) heat to dry the mud entering the kiln. Generally both systems are not used together due to dusting and installation costs. Comparison of the two approaches is shown Table XX.

Theoretical energy, based on the endothermic reaction, requires 2.48 MMBtu/t lime (0.69 MM Btu/adt pulp) [27]. Based on theoretical energy requirements, the opportunity to reduce direct fuel from design BAT is about 35%. Practical Minimum Technology was determined by assuming a 35% reduction in energy consumption from the new kiln BAT number of 1.38 MM Btu/fst.

Energy consumption saving in new kilns vs. an older kiln with modern internals is about 8% to 17%. Energy savings for new kiln design vs. conventional kilns is about 25%. Going with auto causticizing eliminates the kiln and auxiliary equipment, including the direct fuel and electrical load. Partial auto causticizing is being done at several mills in the U.S. and Europe. Figure 11 compares the energy requirements using different technologies [28].

Evaporators

Liquor evaporation accounts for almost 17% of the energy consumed during pulp and paper manufacture. Average black liquor evaporation steam requirement was estimated at 3.5 MMBtu/adst and BAT at 3.0 (Figure 7).

Calculation of Practical Minimum energy consumption in evaporation was based on use of membrane technology to dewater from 22 to 30% black liquor solids, followed by multiple effect evaporation to 80% solids. This was based on recent work demonstrating use of ultrafiltration to concentrate black liquor to over 30% solids [29]. Result is an estimated steam usage of 2.2 MMBtu/bdst. Assumptions for the calculation include:

- Sensible heat increase
- Latent heat of vaporization is obtained by dividing by number of effects to take into account use of vapor to heat subsequent effects.
- Heat Transferred = Heat usage (heat sink) = Sensible Heat to Bring Liquor to Boiling Temp + Latent Heat of Vapor Produced (Water Evaporated)/(number of effects)

Electrical power requirement in the membrane separation step was estimated at 16 kWh/adt, which compares favorably with the overall average case power requirement of 40 kWh/adt (Figure 7) [30].

Theoretical minimum energy consumption in evaporation was estimated at 1.9 MM Btu/adt pulp, again assuming membrane separation up to 30% solids followed by 4-effect evaporation (sensible heat increase plus latent heat of vaporization). The summary chart shows average, BAT, Practical Minimum and Theoretical Minimum cases (Figure 12).

Technologies that Can Help Achieve Practical Minimum Energy Consumption

Technologies that have been evaluated in the laboratory and/or have been commercially applied to a limited extent include:

- Black Liquor and Hog Fuel Gasification - There have been several demonstration and commercial units built for both liquor and hog fuel gasification. All existing units in the United States have been atmospheric units; a pressurized pilot gasifier unit is located in Sweden [31]. Initial work has identified significant improvement in energy efficiency if a pressurized gasifier were connected to a combined cycle gas turbine. Electrical generating efficiency of a Tomlinson boiler is 16.3% vs. 21.1% for a mill scale high-temperature gasifier [32]. Black Liquor provides 20-25 GJ/admt (17.2-21.5 MMBtu/adst) of energy [33]. Estimates have been made of potential steam and electrical production (net of cogeneration plant) at a kraft mill from bark (4 MJ/admt) (3.4 Btu/lb) and black liquor (21 MJ/admt) (18.1 Btu/lb) fuels using alternative cogeneration technologies. The cogeneration technologies include a condensing extraction steam turbine (CEST) and the black liquor/bark integrated gasification/gas turbine combined cycle (liquor and bark are processed separately).

- Auto causticizing - Auto causticizing is theoretically viable and has been demonstrated in the lab. Elimination of the lime kiln and all the associated causticizing equipment would save significant energy. The lime kiln in many kraft mills is the major consumer of direct (fossil) fuels. Commercialization has been hindered by the cost of the required catalysts; however there are several mills in the U.S. and Europe running partial auto causticizing. Auto causticizing can potentially be coupled with black liquor gasification, with use of specific agents at low or high pressure. Borate systems can be used for partial conversions (booster systems to augment existing capacity) while titanates can be used for 100% conversion, eliminating the lime kiln.

- Biorefinery - Much has been discussed about the biorefinery concept in recent years [34, 35]. It is a component of AF&PA's Agenda 2020. Extracting hydrogen, and other chemical feed stock, from wood chips prior to pulping has the potential for a significant change in the way pulp mills utilize / produce energy. Net energy efficiency impact of a biorefinery is currently being investigated [36].

SUMMARY

The distribution of energy used, based on MECS in the pulp and paper industry was determined. The energy consumed in the powerhouse is the energy that is used within the powerhouse due to boiler efficiency, soot blowing, steam venting, and turbine and transformer efficiency, and is not the energy that exits the powerhouse to be used in the manufacturing processes.

By applying BAT – current design practices for the most modern mills - energy consumption within the Pulp and Paper Industry was found to be improved by 22.9% for an annual use estimate of 1,821 TBtu vs. the MECS data of 2,361 TBtu. Purchased energy, excluding electric power, can be reduced from 886 TBtu (MECS case) to 517 TBtu (BAT Case), a 41.7% reduction. BAT calculations were based on the MECS energy distribution matrix. Published design unit energy consumptions for new or modern mill designs (vs. MECS unit consumption being "average" for 90 vintage mills) were used to back calculate energy consumption.

The six major consumers by area within Pulp and Paper manufacturing were identified. These six areas account for 78.8% (1,280 TBtu) of the 1,623 TBtu used in manufacturing under MECS and 83.6% (915 TBtu) of the 1,217 TBtu with BAT. Paper drying and liquor evaporation are self-explanatory. Paper Machine Wet End is the energy consumed in stock preparation ahead of the paper machine and, includes refining, cleaning and screening, pumping of stocks, forming and pressing, etc. Pulping Chemical Preparation is the energy used in the pulp mill for chemical preparation, such as white liquor, and includes energy consumed in the lime kiln. Wood cooking is the energy consumed in the cooking of chemical pulps (sulfite, kraft and NSSC) and does not include the energy used for refining and grinding in the preparation of mechanical pulps, e.g. stone groundwood and TMP.

Overall kraft pulping, bleached and unbleached, which accounts for 57% of the pulp production, accounts for 76% of the energy consumed for pulp production. Linerboard, and printing and writing grades, which combined account for 78% of the paper production (52% and 26% respectively), account for 39% of the energy consumed in paper manufacturing (24% and 15% respectively).

Comparison was made of current energy consumption vs. BAT, Practical Minimum and Theoretical Minimum energy consumption for paper drying, liquor evaporation and lime kiln (Figures 10-12). The potential energy savings (bandwidth) between BAT and Practical Minimum are:

- Paper Drying – 66%
- Liquor Evaporation – 27%
- Lime Kiln – 35%

Paper Drying shows the largest gap and potential energy reduction (Figure 13). Practical Minimum and Theoretical Minimum reflect changes in paper drying, evaporation and lime kiln direct fuel reflected in Figures 2.5, 2.6 and 2.7. No other changes have been made.

Figure 14 shows the impact on purchased fuels by applying BAT and the three Practical Minimum technologies shown above. Shown is a 42% reduction in purchased Fossil fuel between MECS and BAT and 80% reduction between MECS and Practical Minimum. Reductions in total purchased energy are 40% and 72% respectively. Additional research to reduce these and other large energy use areas within the Pulp and Paper Industry may allow the industry to be a net exporter of energy rather than a consumer.

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Table I. 2002 MECS (Table 3.2) Energy Consumed, Paper Industry, NAICS 322

	TBtu	%
Net Electricity	223	9.4
Coal	234	9.9
Residual Fuel Oil	100	4.2
Distillate Fuel Oil	13	0.6
Natural Gas	504	21.3
LPG & NGL	6	0.3
Coke and Other	1,281	54.3
Total Energy	**2,361**	**100.0**

Table II. 2002 MECS (Table 3.5), Selected By-Products, Paper Industry, NAICS 322

Type	TBtu
Waste Gas	1
Waste Pulping Liquors	820
Wood and Bark	316
Other By Products	21
Total	**1,158**

Table III. 2002 MECS (Table 11.3), Components of On-site Generation Paper Industry, NAICS 322

Component	Million kWh
Cogeneration	45,687
Renewable, except wood & biomass	2,243
Other	3,278
Total On-site Generation	**51,208**

Table IV. AF&PA 2000 - 2002 Statistics Estimated Fuel and Energy Used

Source	AF&PA 2000	
	TBtu	%
Purchased Electricity	155	7.1
Purchased Steam	34	1.6
Coal	266	12.2
No. 2 Oil	93	4.3
No. 6 Oil	9	0.4
Natural Gas	396	18.2
LPG	1	0.1
Other Purchased	23	1.0
Energy Sold	(45)	-2.1
Total Purchased	**932**	**42.8**
Hog	327	15.0
Black Liquor	895	41.1
Hydro Power	5	0.2
Other	20	0.9
Self Generated	**1,247**	**57.2**
Total Energy	**2,179**	**100.0**

Table V. AF&PA 2002 Statistics, Year 2000 Shipments

Paper Product	(1,000 tons)	% of Total
Corrugating Medium	9,789	9.3
Linerboard	23,484	22.2
Recycled Board	2,042	1.9
Gypsum Board	1,416	1.3
Folding Boxboard	5,254	5.0
Bleached Folding Boxboard / Milk	6,484	6.1
Other Board, unbleached	504	.05
Kraft paper	1,707	1.6
Special Industrial	2,396	2.3
Newsprint	7,241	6.9
Groundwood Specialties	1,832	1.7
Coated Groundwood	4,622	4.4
Bleached Packaging	329	0.3
Bleached Bristol	1,487	1.4
Uncoated Freesheet	13,898	13.2
Coated Freesheet	4,993	4.7
Other Specialties	104	0.1
Tissue & Towel	6,911	6.5
Subtotal	**94,491**	**89.5**
Kraft Pulp, bleached	8,013	7.6
Kraft Pulp, unbleached	292	0.3
Sulfite Pulp	108	0.1
Recycled Pulp	1,677	1.6
Other Pulp / Dissolving Pulp	1,006	1.0
Subtotal	**11,096**	**10.5**
Total	**105,587**	**100.0**

Table VI. AF&PA 2002 Statistics, Year 2000 Pulp Production

Type	(1,000 tons)	% of Total
Bleached Sulfite	1,169	1.3
Unbleached Kraft	21,200	23.0
Bleached Kraft Softwood	14,181	15.4
Bleached Kraft Hardwood	16,580	18.0
NSSC	3,955	4.3
SWG	1,924	2.1
TMP	3,749	4.1
OCC	16,973	18.4
Non Deinked MOW	3,711	4.0
Deinked MOW	2,347	2.5
Deinked ONP	4,410	4.8
Pulp Substitutes	1,890	2.1
Total	**92,089**	**100.0**

Table VII. Average Powerhouse Energy Consumption

	MECS 2002 Table 3.2 NAICS 322	Fuel Utilized In Boilers	Boiler Efficiency	Net Energy	Used for Soot Blowing Steam	Used for Boiler Aux.	Net Energy	Percent of Energy Used to Generate Electricity	Electrical Generation Conversion Loss	System & Mechanical Loss	Total Available for Process	Electricity	Electricity	Direct Fuel	Steam	% of Feed Available for Process
	TBtu	%	%	TBtu	%	%	TBtu	%	%	%	TBtu	TBtu	BkWh	TBtu	TBtu	%
Purchased Electricity	223	0%	98%	223	0%	0%	223	0%	9%	2%	218.5	218.5	64.1			98%
Coal	234	100%	87%	204	2.5%	6.0%	186	19%	9%	6%	172.1	30.3	8.9	-	141.8	74%
Residual Fuel Oil	100	100%	87%	87	0%	4.0%	84	19%	9%	6%	77.2	13.6	4.0	-	63.6	77%
Distillate Fuel Oil	13	70%	87%	12	0%	3.0%	11	0%	9%	6%	10.8	-	-	3.2	7.5	83%
Natural Gas	504	70%	88%	462	0%	3.0%	448	5%	9%	6%	419.1	18.5	5.4	120.2	280.4	83%
LPG	6	0%	88%	6	0%	0.0%	6	0%	9%	0%	6.0	-	-	6.0	-	100%
Waste Pulping Liquors	820	100%	65%	533	7.5%	4.0%	472	19%	9%	6%	435.8	76.7	22.5	-	359.2	53%
Wood / Bark	316	100%	70%	221	1.5%	5.0%	207	19%	9%	6%	191.1	33.6	9.9	-	157.5	60%
Other By Products	22	80%	70%	17	0%	4.0%	16	0%	9%	6%	15.1	-	-	3.0	12.1	69%
Other	123	100%	70%	86	0%	4.0%	83	3%	9%	6%	77.5	2.1	0.6	-	75.4	63%
Subtotal - Fuels	2,138			1,627			1,512				1,405	174.7	51.2	132.4	1,097.5	66%
Total	**2,361**			**1,850**			**1,735**				**1,623**	**393.3**	**115.3**	**132.4**	**1,097.5**	**69%**

Boiler Efficiencies: conversion efficiency of the boiler, based on Jacobs’ design rule of thumb.

Soot Blowing Steam: steam used in the boiler for tube cleaning, based on Jacobs’ design rule of thumb.

Boiler Auxiliaries: include energy consumed for fans, pumps, coal crushers, bark hogs, environmental controls, steam leaks and venting, etc.

Electrical Generator Conversion Loss: energy / heat loss in generator and condenser.

System ands Mechanical Loss: energy / heat loss in transformers, radiation losses form pipes, venting and leaks.

Electricity generated on-site is 51.21 BkWh (44% of the total 115 BkWh electricity used by the processes.

Total fuel consumed by the industry is 2,138 TBtu of which 1,405 TBtu (66% of the feed) is available for use in the pulp and paper manufacturing processes after the powerhouse (including 132 TBtu of fuel used directly as fuel in the process). The 2,006 TBtu difference between 2,138 TBtu and 132 TBtu is the fuel consumed in the powerhouse to co-generate the 1,272 TBtu of process steam and electricity.

Table VIII. Energy Distribution Overview – Average Case

	Elec kWh/t	Elec MMBtu/t	Steam MMBtu/t	Direct Fuel MMBtu/t	Production 1000 t/yr	Production %	Elec Million kWh	Electric TBtu	Steam TBtu	Direct Fuel TBtu	Total TBtu
Sulfite	405.7	1.4	7.64	1.76	1,169	1.3%	474	1.6	8.9	2.1	12.6
Kraft, Bleached, SW	452.1	1.5	8.35	1.96	14,181	15.4%	6,411	21.9	118.3	27.7	168.0
Kraft, Bleached, HW	405.7	1.4	8.14	1.96	16,580	18.0%	6,727	23.0	135.0	32.4	190.4
Kraft, UnBleached	347.8	1.2	6.54	1.86	21,200	23.0%	7,373	25.2	138.5	39.4	203.1
SGW	2,132.9	7.3	3.02	0.00	1,924	2.1%	4,104	14.0	5.8	0.0	19.8
TMP	2,579.2	8.8	0.70	0.00	3,749	4.1%	9,669	33.0	2.6	0.0	35.6
SemiChem	527.4	1.8	6.13	1.16	3,955	4.3%	2,086	7.1	24.3	4.6	36.0
OCC	347.8	1.2	0.80	0.00	16,973	18.4%	5,903	20.1	13.7	0.0	33.8
MOW, non deinked (tissue)	405.7	1.4	0.80	0.00	3,711	4.0%	1,506	5.1	3.0	0.0	8.1
MOW, deinked	521.6	1.8	1.41	0.00	2,347	2.5%	1,224	4.2	3.3	0.0	7.5
ONP, deinked	434.7	1.5	1.41	0.00	4,410	4.8%	1,917	6.5	6.2	0.0	12.7
Pulp Sub	104.3	0.4	0.00	0.00	1,890	2.1%	197	0.7	0.0	0.0	0.7
Sub Total					**92,089**	**100.0%**	**47,591**	**162.4**	**459.7**	**106.2**	**728.3**
Linerboard	666.5	2.3	5.83	0.00	23,484	22.2%	15,653	53.4	136.9	0.0	190.4
Recycled Board	579.6	2.0	5.83	0.00	2,042	1.9%	1,184	4.0	11.9	0.0	15.9
Bl Folding Boxboard & Milk	637.6	2.2	5.83	0.00	6,484	6.1%	4,134	14.1	37.8	0.0	51.9
Kraft Paper	608.6	2.1	5.23	0.00	1,707	1.6%	1,039	3.5	8.9	0.0	12.5
Special Industrial	608.6	2.1	5.23	0.00	2,396	2.3%	1,458	5.0	12.5	0.0	17.5
Gypsum	579.6	2.0	5.83	0.00	1,416	1.3%	821	2.8	8.3	0.0	11.1
Corr. Medium	521.6	1.8	5.73	0.00	9,789	9.3%	5,106	17.4	56.1	0.0	73.5
P&W, Bristols & Bl Pkg	602.8	2.1	5.49	0.00	15,714	14.9%	9,472	32.3	86.3	0.0	118.6
News	521.6	1.8	4.42	0.00	7,241	6.9%	3,777	12.9	32.0	0.0	44.9
GWD Specialities	521.6	1.8	4.42	0.00	1,832	1.7%	956	3.3	8.1	0.0	11.4
Coated Groundwood	579.6	2.0	4.73	0.88	4,622	4.4%	2,679	9.1	21.8	4.1	35.1
Coated Free	672.3	2.3	5.43	0.88	4,993	4.7%	3,357	11.5	27.1	4.4	43.0
Boxboard, unbl	597.0	2.0	5.83	0.88	5,254	5.0%	3,137	10.7	30.6	4.6	46.0
Tissue	695.5	2.4	4.02	1.86	6,911	6.5%	4,807	16.4	27.8	12.8	57.0
Other paper & boards	608.6	2.1	5.53	0.39	606	0.6%	369	1.3	3.4	0.2	4.8
Market Pulp	149.8	0.5	2.94	0.00	11,096	10.5%	1,662	5.7	32.6	0.0	38.2
Sub Total					**105,587**	**100.0%**	**59,609**	**203.4**	**542.2**	**26.2**	**771.7**
Wastewater & Utilities	76.5	0.3	0.90	0.00	105,587		8,078	27.6	95.5	0.0	123.1
Grand Total							**115,278.2**	**393.33**	**1,097.43**	**132.42**	**1,623.2**

Table IX. U.S. P&P Energy Distribution

	Electric		Steam		Direct Fuel	
	TBtu	**%**	**TBtu**	**%**	**TBtu**	**%**
Pulp Manufacture	162.4	41.3	459.9	41.9	106.3	80.3
Paper Manufacture	203.4	51.7	542.3	49.4	27.2	19.7
Utilities, excluding Powerhouse	27.6	7.0	95.2	8.7	0.0	0
Total Manufacturing	**393.4** (24.2%)	100.0	**1,097.4** (67.6%)	100.0	**132.4** (8.2%)	100.0
Grand Total	**1,623.2** (100.0%)					

Table X. Energy Use within Pulp Manufacturing

	Electrical Energy		Steam Energy		Direct Fuel Energy	
	TBtu	%[4]	TBtu	%[4]	TBtu	%[4]
Wood Preparation	15.0	9.2	15.6	3.4	0.0	0.0
Cooking[1]	19.7	12.1	115.4	24.9	0.0	0.0
Grinding / Refining[2]	41.4	25.5	-3.4	-0.7	0.0	0.0
Screening / Cleaning[3]	14.1	8.7	0.0	0.0	0.0	0.0
Evaporation	9.3	5.7	203.0	44.2	0.0	0.0
Chemical Preparation	10.0	6.2	32.5	7.0	106.2	100.0
Bleaching	16.3	10.0	70.7	15.4	0.0	0.0
Recycle / Pulp Subs	36.7	22.6	26.1	5.7	0.0	0.0
Total	**162.4** (22.3%)	100.0	**459.9** (63.1%)	100.0	**106.2** (14.6%)	100.0
Grand Total	**728.5** (100.0%)					

1. For chemical pulps includes digesting through washing
2. Includes heat recovery for TMP refiners
3. Screening & cleaning for mechanical pulping, energy for screening & cleaning of chemical pulp is in the cooking numbers
4. The percentages above represent an overall average for all pulping processes and vary for individual processes (e.g., kraft, NSSC, etc.)

Table XI. Energy Use within Paper Manufacturing

	Electrical Energy		Steam Energy		Direct Fuel Energy	
	TBtu	%[3]	TBtu	%[3]	TBtu	%[3]
Wet End[1]	107.4	52.8	116.8	21.5	0.0	0.0
Pressing	35.4	17.4	0.0	0.0	0.0	0.0
Drying	38.1	18.7	421.3	77.7	12.8	49.2
Dry End[2]	19.8	9.7	0.0	0.0	0.0	0.0
Coating Preparation	0.8	0.4	1.5	0.3	0.0	0.0
Coating Drying	0.0	0.0	0.0	0.0	13.3	450.8
Super Calendering	2.0	1.0	2.8	0.5	0.0	0.0
Total	**203.5** (26.3%)	100.0	**542.3** (70.3%)	100.0	**26.1** (3.4%)	100.0
Grand Total	**771.9** (100.0%)					

1. Wet End includes stock preparation through forming
2. Dry End includes calendering through winding
3. The percentages above represent an overall average for all papermaking processes and vary for individual processes (e.g., liner, uncoated freesheet, tissue, etc.)

Table XII. Comparison of Total Mill Net Fuel Demand Versus MECS

COMPARISON OF TOTAL MILL NET FUEL DEMAND VERSUS MECS							
	Basis MMton/yr	Electric Energy kWh/ton	Steam Energy MMBtu/ton	Direct Fuel MMBtu/ton	Total Electric MMkWh	Total Steam TBtu	Direct Fuel TBtu
Total Pulping Process Demand	92.09	516.79	4.99	1.15	47,591	459.9	106.2
Total Papermaking Demand	105.59	564.55	5.14	0.25	59,609	542.3	26.1
Wastewater Treatment					8,078	95.2	0
Total Industry Proc. Demand	**105.59**	**1091.78**	**10.39**	**1.25**	**115,278**	**1,097.4**	**132.3**
Total Boilers Gross (Gen)	105.59				(51,210)	(1097.4)	2006.0
Power Plant Demand	105.59				1,307		
Net Total Boilers Demand	**105.59**				**(49,903)**	**(1,097)**	**2,006**
Total Mill Demand w/Direct					**65,375**	**0**	**2,138.3**
MECS Industry Demand					**65,358**	**0.0**	**2,138.0**

Table XIII. BAT Energy Distribution Overview

	Current Electric kWh/t	BAT Electric kWh/t	BAT Electric MMBtu/t	Electric % change	Current Steam MMBtu/t	BAT Steam MMBtu/t	Steam % change	Current Direct Fuel MMBtu/t	BAT Direct Fuel MMBtu/t	Direct Fuel % change	Production 1000 t/yr	Production %	Elec Million kWh	Electric TBtu	Steam TBtu	Direct Fuel TBtu	Total TBtu
Sulfite	406	406	1.4	0.0%	7.6	7.64	0.0%	1.8	1.8	0.0%	1,169	1.3%	474	1.6	8.9	2.1	12.6
Kraft, Bleached, SW	452	363	1.2	-19.7%	8.3	6.34	-24.0%	2.0	1.4	-30.0%	14,181	15.4%	5,148	17.6	89.9	19.4	126.9
Kraft, Bleached, HW	406	347	1.2	-14.5%	8.1	5.58	-31.5%	2.0	1.3	-36.1%	16,580	18.0%	5,753	19.6	92.5	20.7	132.9
Kraft, UnBleached	348	269	0.9	-22.6%	6.5	4.66	-28.7%	1.9	1.5	-20.4%	21,200	23.0%	5,703	19.5	98.8	31.4	149.6
SGW	2133	2,133	7.3	0.0%	3.0	3.00	-0.5%	0.0	0.0		1,924	2.1%	4,104	14.0	5.8	0.0	19.8
TMP	2579	2,088	7.1	-19.0%	0.7	0.58	-17.6%	0.0	0.0		3,749	4.1%	7,828	26.7	2.2	0.0	28.9
SemiChem	527	527	1.8	0.0%	6.1	5.00	-18.5%	1.2	1.2	-1.2%	3,955	4.3%	2,086	7.1	19.8	4.5	31.4
OCC	348	206	0.7	-40.8%	0.8	0.60	-25.4%	0.0	0.0		16,973	18.4%	3,496	11.9	10.2	0.0	22.1
MOW, non deinked (tissue)	406	348	1.2	-14.2%	0.8	0.60	-25.4%	0.0	0.0		3,711	4.0%	1,291	4.4	2.2	0.0	6.6
MOW, deinked	522	472	1.6	-9.5%	1.4	1.33	-5.5%	0.0	0.0		2,347	2.5%	1,108	3.8	3.1	0.0	6.9
ONP, deinked	435	395	1.3	-9.1%	1.4	1.33	-5.5%	0.0	0.0		4,410	4.8%	1,742	5.9	5.9	0.0	11.8
Pulp Sub	104	104	0.4	0.0%	0.0	0.00	0.0%	0.0	0.0		1,890	2.1%	197	0.7	0.0	0.0	0.7
Sub Total											**92,089**	**100.0%**	**38,930**	**132.8**	**339.3**	**78.1**	**550.2**
Linerboard	667	467	1.6	-29.9%	5.8	3.08	-47.2%	0.0	0.0		23,484	22.2%	10,967	37.4	72.3	0.0	109.8
Recycled Board	580	310	1.1	-46.5%	5.8	4.00	-31.4%	0.0	0.0		2,042	1.9%	633	2.2	8.2	0.0	10.3
Bl Folding Boxboard & Milk	638	467	1.6	-26.8%	5.8	3.08	-47.2%	0.0	0.0		6,484	6.1%	3,028	10.3	20.0	0.0	30.3
Kraft Paper	609	467	1.6	-23.3%	5.2	3.08	-41.1%	0.0	0.0		1,707	1.6%	797	2.7	5.3	0.0	8.0
Special Industrial	609	467	1.6	-23.3%	5.2	3.08	-41.1%	0.0	0.0		2,396	2.3%	1,119	3.8	7.4	0.0	11.2
Gypsum	580	310	1.1	-46.5%	5.8	4.00	-31.4%	0.0	0.0		1,416	1.3%	439	1.5	5.7	0.0	7.2
Corr. Medium	522	467	1.6	-10.5%	5.7	3.08	-46.3%	0.0	0.0		9,789	9.3%	4,571	15.6	30.2	0.0	45.7
P&W, Bristols & Bl Pkg	603	455	1.6	-24.5%	5.5	4.16	-24.2%	0.0	0.0		15,714	14.9%	7,150	24.4	65.4	0.0	89.8
News	522	323	1.1	-38.1%	4.4	3.32	-25.0%	0.0	0.0		7,241	6.9%	2,339	8.0	24.0	0.0	32.0
GWD Specialities	522	323	1.1	-38.1%	4.4	3.96	-10.5%	0.0	0.0		1,832	1.7%	592	2.0	7.3	0.0	9.3
Coated Groundwood	580	550	1.9	-5.1%	4.7	4.44	-6.0%	0.9	0.9	0.0%	4,622	4.4%	2,542	8.7	20.5	4.1	33.3
Coated Free	672	495	1.7	-26.4%	5.4	3.83	-29.5%	0.9	0.9	0.0%	4,993	4.7%	2,472	8.4	19.1	4.4	31.9
Boxboard, unbl	597	310	1.1	-48.1%	5.8	4.00	-31.4%	0.9	0.9		5,254	5.0%	1,629	5.6	21.0	4.6	31.2
Tissue	696	669	2.3	-3.8%	4.0	3.96	-1.5%	1.9	1.9	0.0%	6,911	6.5%	4,623	15.8	27.4	12.8	56.0
Other paper & boards	609	467	1.6	-23.3%	5.5	4.00	-27.7%	0.4	0.4		606	0.6%	283	1.0	2.4	0.2	3.6
Market Pulp	150	145	0.5	-3.2%	2.9	2.53	-13.8%	0.0	0.0		11,096	10.5%	1,609	5.5	28.1	0.0	33.6
Sub Total											**105,587**	**100.0%**	**44,793**	**152.8**	**364.1**	**26.2**	**543.1**
Wastewater & Utilities	77	77	0.3	0.0%	0.9	0.90	-0.4%	0.0	0.0		105,587		8,077	27.6	95.2	0.0	122.7
Grand Total													**91,800.4**	**313.22**	**798.56**	**104.31**	**1,216.1**
Current (MECS)													115,278.2	393.33	1,097.43	132.42	1,623.2
Difference, %													**-20.4%**	**-20.4%**	**-27.2%**	**-21.2%**	**-25.1%**

Table XIV. Powerhouse Energy Consumption after BAT

`	Estimate Based on BAT	Fuel Utilized In Boilers	Boiler Efficiency	Net Energy	Used for Soot Blowing Steam	Used for Boiler Aux.	Net Energy	Percent of Energy Used to Generate Electricity	Electrical Generation Conversion Loss	System & Mechanical Loss	Total Available for Process	Electricity	Electricity	Direct Fuel	Steam	% of Feed Available for Process
	TBtu	**%**	**%**	**TBtu**	**%**	**%**	**TBtu**	**%**	**%**	**%**	**TBtu**	**TBtu**	**BkWh**	**TBtu**	**TBtu**	**%**
Purchased Electricity	152	0%	98%	152	0%	0%	152	0%	9%	2%	149.1	149.1	43.7	-	-	98%
Coal	171	100%	88%	150	2.0%	6.0%	138	19%	9%	6%	127.6	24.2	7.1	-	103.4	75%
Residual Fuel Oil	72	100%	88%	63	0%	4.0%	61	19%	9%	6%	56.2	10.6	3.1	-	45.6	78%
Distillate Fuel Oil	9	70%	88%	9	0%	3.0%	8	0%	9%	6%	7.9	-	-	2.5	5.4	83%
Natural Gas	192	70%	89%	177	0%	3.0%	171	5%	9%	6%	160.4	3.4	1.0	94.7	62.3	84%
LPG	5	0%	88%	5	0%	0.0%	5	0%	9%	0%	4.7	-	-	4.7	-	100%
Waste Pulping Liquors	820	100%	68%	558	5.5%	4.0%	505	19%	9%	6%	465.9	88.2	25.9	-	377.6	57%
Wood / Bark	316	100%	70%	221	1.0%	5.0%	208	19%	9%	6%	192.0	36.4	10.7	-	155.6	61%
Other By Products	17	80%	70%	12	0%	4.0%	12	0%	9%	6%	11.2	-	-	2.4	8.8	67%
Other	65	100%	70%	46	0%	4.0%	44	3%	9%	6%	41.2	1.3	0.4	-	39.9	63%
Subtotal - Fuels	1,668			1,241			1,153				1,067	139.2	48.1	104.3	798.6	64%
Total	**1,820**			**1,393**			**1,305**				**1,216.13**	**313.22**	**91.80**	**104.31**	**798.56**	**67%**
2000 MECS	2,361			1,850			1,735				1,623	393.3	115.3	132.4	1097.5	
Difference, %	**-22.9%**			**-24.7%**			**-24.8%**				**-25.1%**	**-20.4%**	**-20.4%**	**-21.2%**	**-27.2%**	

Table XV. U.S. P&P Energy Distribution – Average (MECS) Versus BAT

	Electric			Steam			Direct Fuel		
	MECS TBtu	BAT TBtu	Diff. %	MECS TBtu	BAT TBtu	Diff. %	MECS TBtu	BAT TBtu	Diff. %
Pulp Manufacture	162.4	132.8	-18.2	459.9	339.3	-26.2	106.2	78.1	-26.5
Paper Manufacture	203.4	152.8	-24.9	542.3	364.3	-32.8	26.1	26.1	0.0
Utilities, excluding Powerhouse	27.6	27.6	0.0	95.2	95.2	0.0	0.0	0.0	0.0
Total Manufacturing	**393.4**	**313.2**	**-20.4**	**1,097.4**	**798.8**	**-27.2**	**132.4**	**104.3**	**-21.2**

Table XVI. Major Energy Consumption Areas

Area	**MECS Energy Consumption TBtu**	**MECS Percent of Total %**	**BAT Energy Consumption TBtu**	**BAT Percent of Total %**
Paper Drying	472	31.5	371	33.9
Paper Machine Wet End	224	14.9	100	9.2
Liquor Evaporation	212	14.2	183	16.7
Chem. Prep including Lime Kiln	149	9.9	90	8.3
Pulp Digesting	135	9.0	109	10.0
Bleaching	87	5.8	61	5.5
Other Processes	221	14.7	182	16.4
Process Total	**1,500**	100.0	**1,094**	100.0

Table XVII. Energy Use Distribution Within the Pulp and Paper Industry- Total MECS vs. Total after Applying BAT

Area	Total Energy Use 2002 MECS TBtu (% of total)	Total Energy Use BAT TBtu (% of total)	BAT Percent Change vs. MECS (%)
Paper Manufacturing	772 (32.7)	543 (29.8)	-29.6
Pulping	728 (30.8)	551 (30.3)	-24.5
Powerhouse Losses	738 (31.3)	604 (33.1)	-18.2
Misc. & Environmental	123 (5.2)	123 (6.7)	0.0
Total Industry Energy Consumption (Purchased and By-product Fuels)	**2,361** (100.0)	**1,820** (100.0)	**-22.9**

Table XVIII. Energy Use by Type within the Pulp and Paper Manufacturing - Total MECS vs. Total After Applying BAT

Type	Total Energy Use by Type 2002 MECS TBtu (% of Total)	Total Energy Use by Type BAT TBtu (% of Total)	BAT Percent Change vs. MECS (%)
Direct Fuel	132 (8.2)	104 (8.6)	-21.2
Electricity	393 (24.2)	313 (25.7)	-20.4
Steam	1,098 (67.6)	799 (65.7)	-27.2
Total Manufacturing	**1,623** (100.0)	**1,216** (100.0)	**-25.1**
Powerhouse Losses	738	604	-18.2
Total Industry	**2,361**	**1,820**	**-22.9**

Table XIX. Major Energy Users by Area within the Pulp and Paper Manufacturing - Total MECS vs. Total after Applying BAT

Area	Total Energy Use by Area 2002 MECS TBtu (% of Total)	Total Energy Use by Area BAT TBtu (% of Total)	BAT Percent Change vs. MECS (%)
Paper Drying	472 (31.5)	371 (33.9)	-21.4
Paper Machine Wet End	224 (14.92)	100 (9.2)	-55.2
Liquor Evaporation	212 (14.2)	183 (16.7)	-13.9
Pulping Chemical Prep	149 (9.9)	90 (8.2)	-39.3
Wood Cooking	135 (9.0)	109 (10.0)	-19.1
Bleaching	87 (5.5)	61 (5.5)	-30.3
Process Sub Total	**1,280** (78.8)	**914** (83.6)	**-28.5**
Other Processes	221 (14.7)	179 (16.4)	-19.0
Total Process	**1,501** (100.0)	**1,093** (100.0)	**-27.1**
Environmental & Utilities	123	123	0.0
Total Manufacturing	**1,623**	**1,216**	**-25.1**

Table XX. Lime Kiln Design Comparison

System Type	Production Factor Ft^3/st/day	Relative Heat Rate[1] MMBtu/st lime (MMBtu/adst pulp)	Relative Power Consumed[1] KWh/st lime (MMBtu/adst pulp)
Conventional Long Kiln	100	7.0 (1.87)	67 (0.061)
Long Kiln retrofitted with modern internals	73-78	6.0 (1.60)	63 (0.056)
New Long Kiln with modern internals, product cooler and ESP	70-75	5.0 (1.34)	45 (0.040)
Kiln with external dryer system and with modern internals, product cooler and ESP	55-60	5.5 (1.47)	50 (0.045)
[1] Mud feed at 75% solids			

Figure 1. Year 2000 U. S. Paper Production

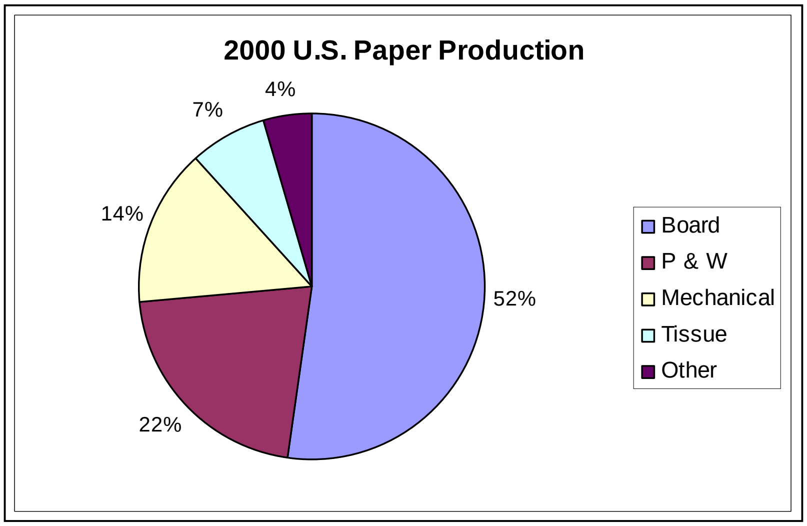

Figure 2. Year 2000 U.S. Pulp Production

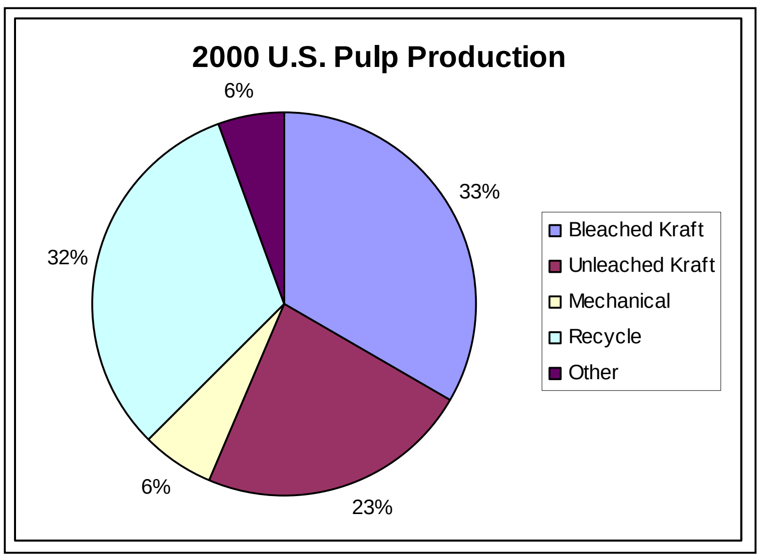

Figure 3. U.S. P&P Energy Use by Pulping Process

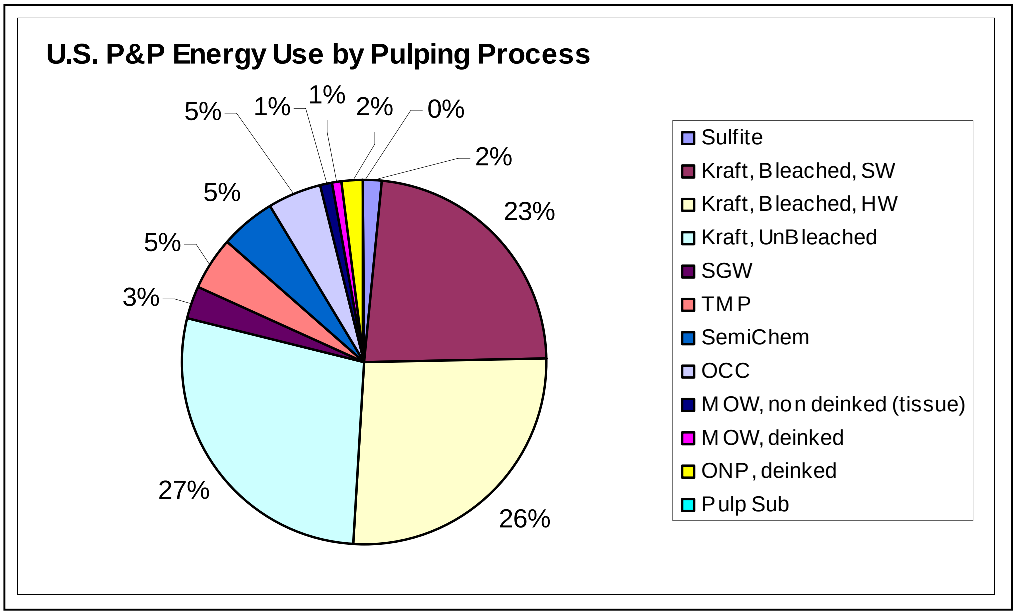

Figure 4. Pulp Mill Energy Use By Type

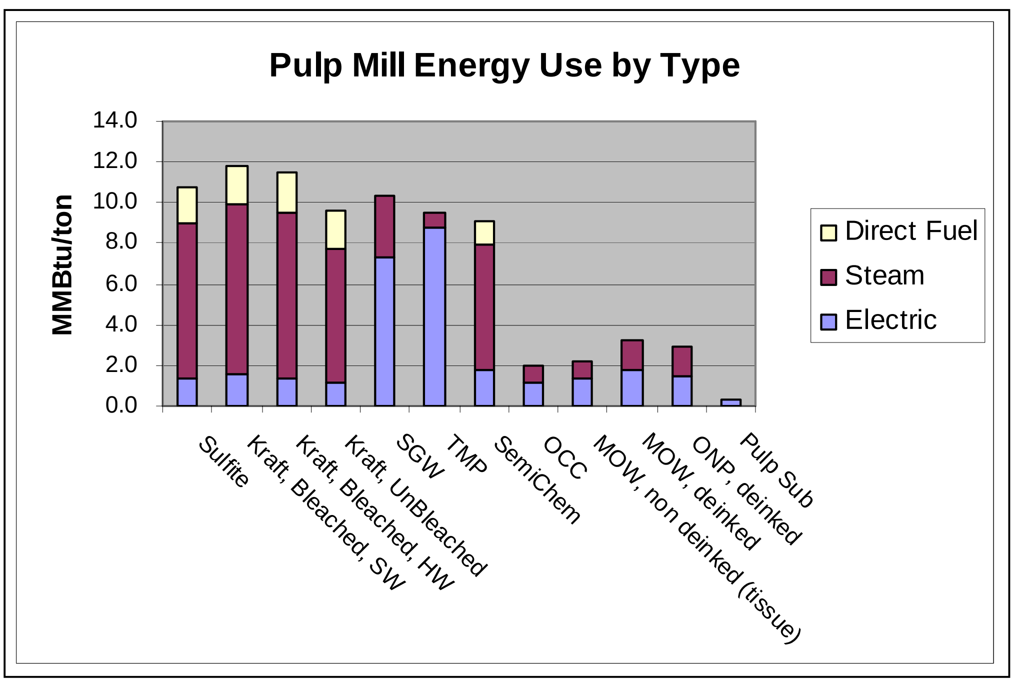

Figure 5. U.S. P&P Energy Use by Paper Production

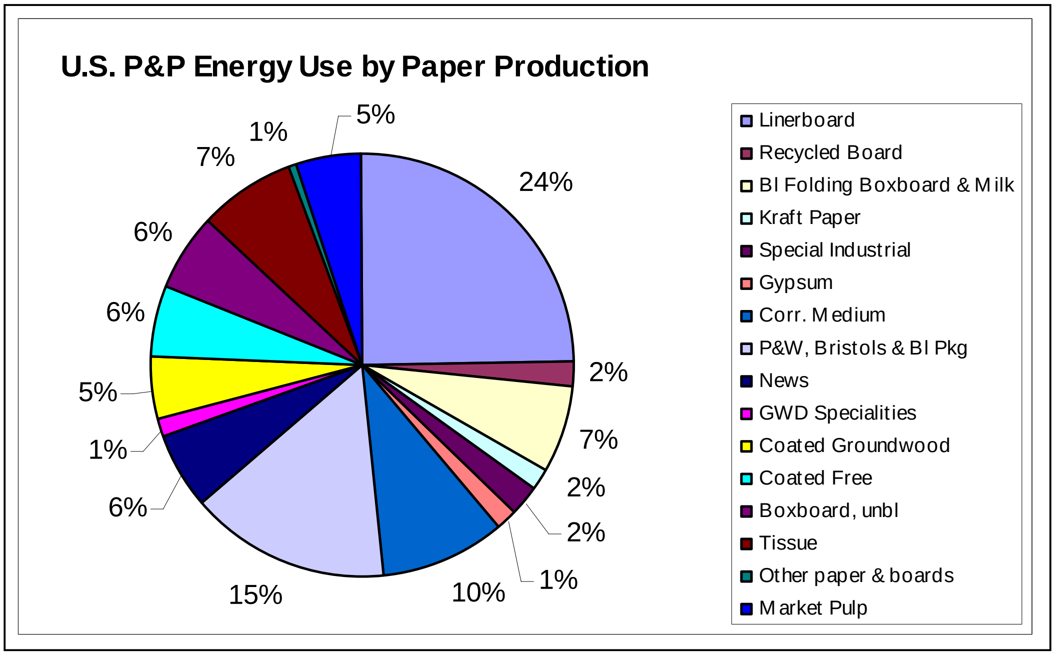

Figure 6. Papermaking Energy Use by Grade

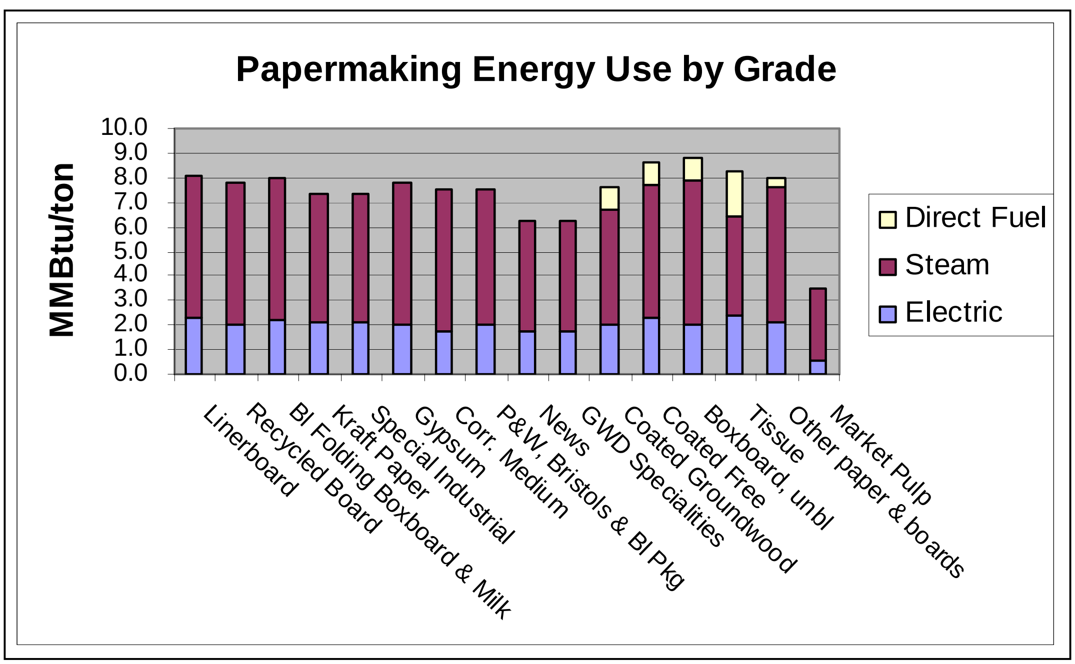

Figure 7. Average Bleached Hardwood Kraft Pulp and Printing and Writing Paper

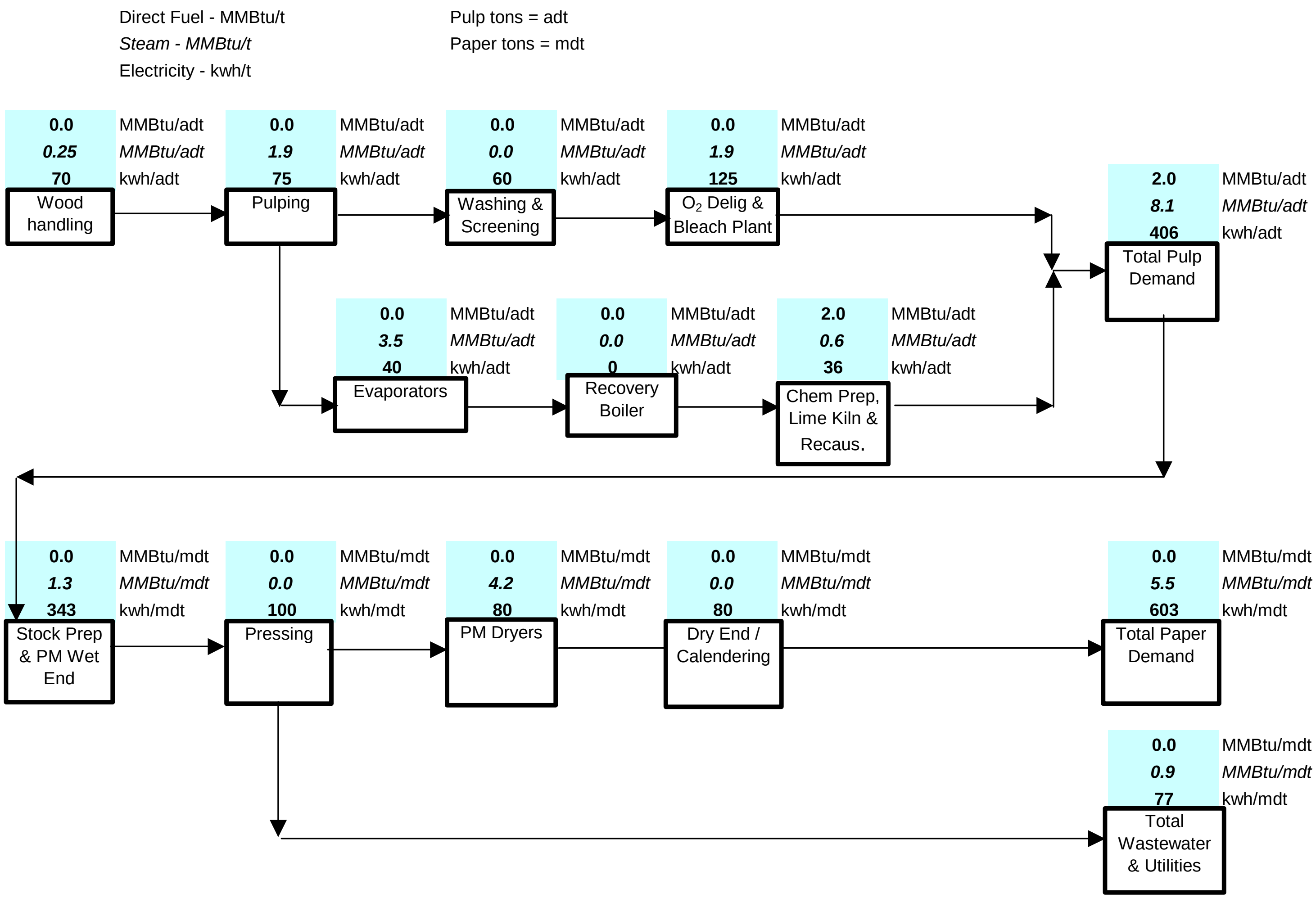

Figure 8. Comparison of Major Energy Areas

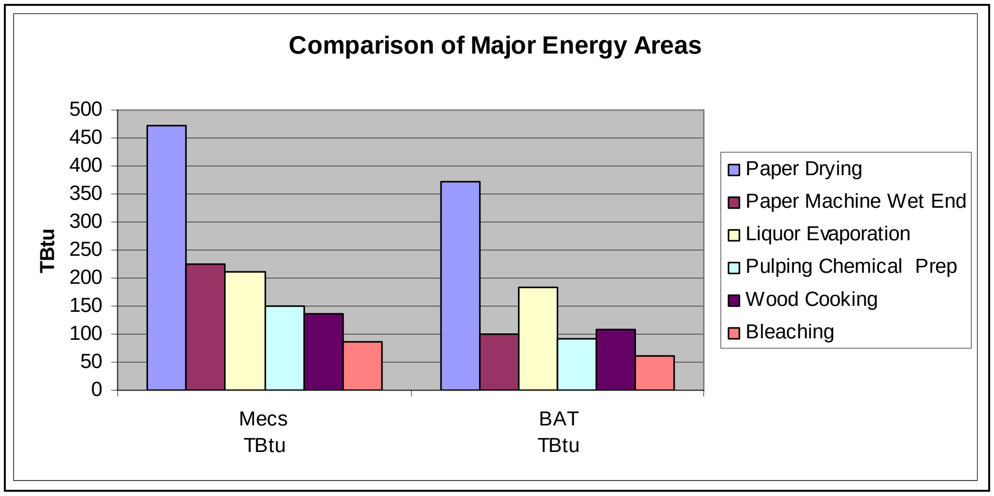

Figure 9. Theoretical Minimum Drying Energy

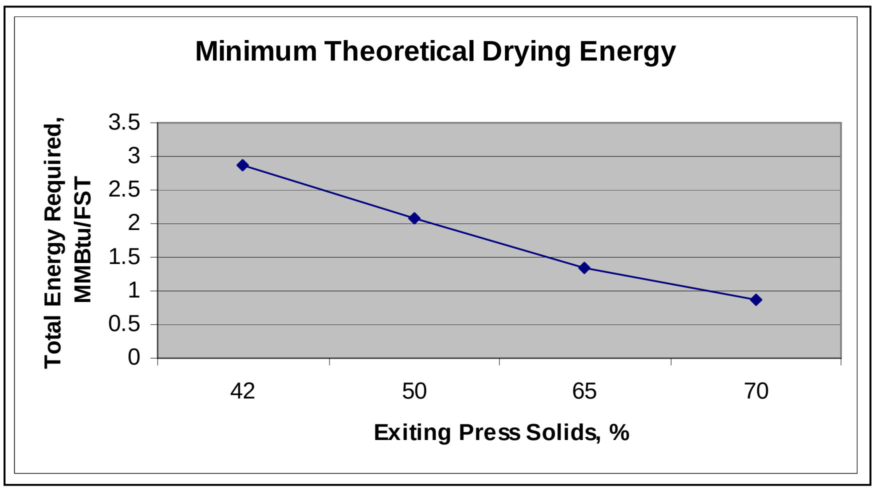

Figure 10. Bandwidth – Drying

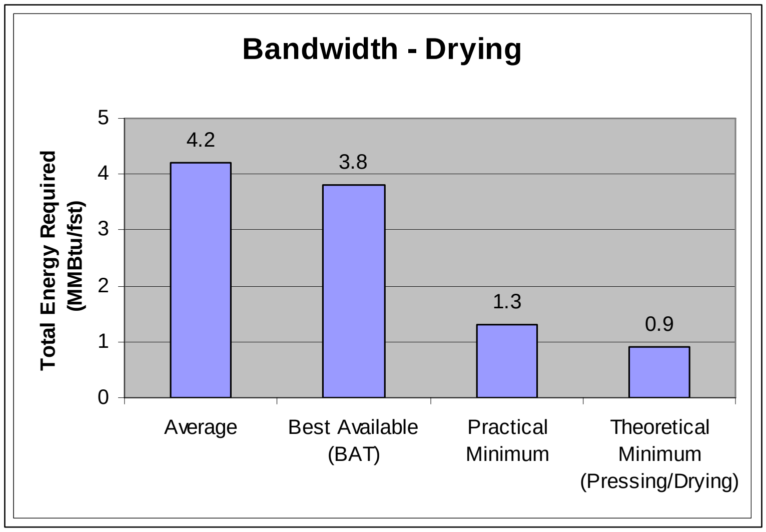

Figure 11. Bandwidth – Lime Kiln

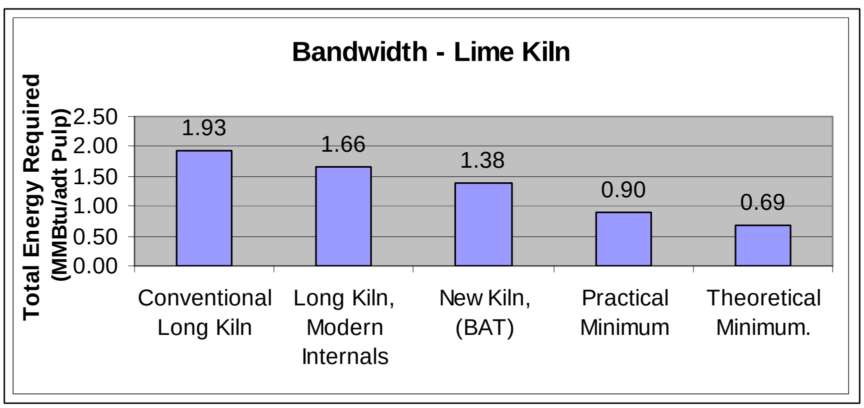

Figure 12. Bandwidth - Evaporation

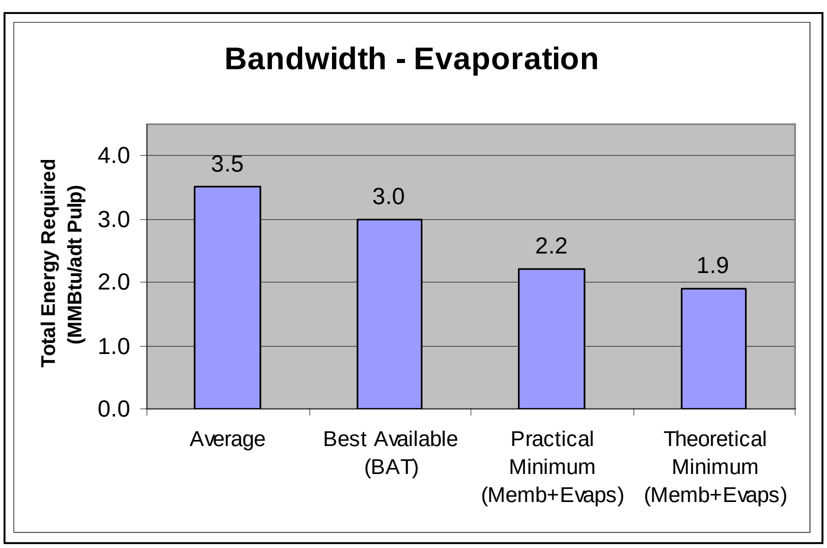

Figure 13. Energy Use Using Applied Technologies

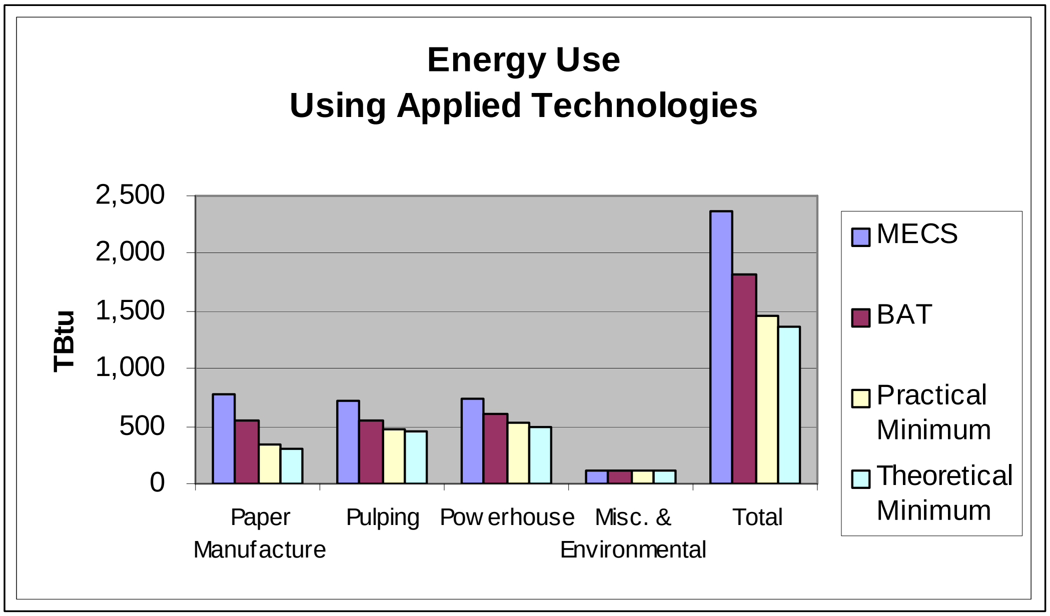

Figure 14. Impact on Purchased Fuels by Applying BAT and Practical Minimum Technologies