Energy Efficiency Measures in the Wood Manufacturing Industry

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ABSTRACT

The objectives of the research are to examine the energy utilization profile of the wood manufacturing industry with respect to system level production parameters and investigate the viability of specific energy efficiency measures. The Industrial Assessment Center (IAC) has conducted energy assessments in the wood manufacturing industrial sector in the State for several years. The energy utilization profile of several wood processing facilities is analyzed and reported. The production system parameters in terms of throughput and nature of manufacturing operations are examined in relation to the overall energy utilization, specific energy consumption, and potential for implementation of energy efficiency measures (EEM).

Introduction

Energy management is the application of engineering principles to the control of energy costs at a facility. It is a continuous process that requires consistent efforts for identifying potential areas for conservation, formulation of proposals and implementation. There are many energy efficient technologies and practices, both currently available and under development, that could save energy if adopted by industry. Energy and energy management have been in the limelight in various manufacturing and service operations across the industries in the US.

Although large quantities of wood are utilized as fuel, pulpwood, and railroad ties, lumber is by far the most important form in which wood is used. In the US, the volume of wood converted into lumber exceeds the volume used for all other purposes. Lumber has been defined as "the product of the saw and planning mill, not further manufactured than by sawing, re-sawing, and passing length wise through a standard planning machine, crosscutting to length and working" (Brown & Smith 1958). As per the "Manufacturing Energy Consumption Survey" published by the Energy Information Administration for the year 1998, in 1997 the annual production of Softwood Lumber and Hardwood Lumber in the US was 34.5 and 12.9 billion board feet respectively (EIA 1998). The US manufacturing plants, mines, farms and constructions firms currently consume about 25 quads (quadrillion British thermal units or Btu) of energy each year, about 30% of the nation's total consumption of energy. The largest energy users are industries such as petroleum refining, chemicals, primary metals, pulp and paper, food and ceramics and glass, which account for 74% of total industrial energy use (Nagarajan 1995). Considering the amount of energy required, there is a recognized need to examine energy efficiency in electricity intensive wood processing facilities (Mate 2002). Manufacturers conduct a number of energy management activities to improve the efficiency of energy use at their facilities. The four significant management techniques used include energy assessments, electricity load controls, power factor improvement, and facility lighting, with energy assessments playing the major role (EIA 1998).

Introduction to the Lumber and Wood Products Industry

The lumber and wood products industry includes facilities engaged in cutting timber and pulpwood; facilities with sawmills, lathe mills, shingle mills, stock mills, planing mills, plywood mills; or the facilities engaged in manufacturing finished wood products. The industrial processes are divided into four general groups: logging timber; producing lumber; panel products and wood preservation. Lumber and wood products include a wide range of products, including cut timber; rough wood products, such as hewn posts; lumber and flooring; millwork, such as moldings and cornices; cabinets; plywood; containers; and wood buildings.

Energy Use in Forest and Wood Products Industry

From the reports published by the Energy Information Administration, the forest products industry consumed more than 3.1 quads of energy in 1994 which represents about 14% of domestic manufacturing energy use. This makes the forest products industry the third largest industrial consumer of energy, behind only petroleum and chemicals. Within the forest products industry, the pulp and paper industry (SIC 26) uses the vast majority of the energy, 2.66 quads, while the lumber and wood products industry uses 0.491 quads. In 1998, the lumber and wood products sector generated 387 trillion Btu (1 Btu = 1.0551 KJ), or 66% of the industry's energy needs, from wood residues. Remaining energy needs were met by electricity, natural gas, and fuel oil. The forest products industry spent $7.7 billion on purchased energy in 1994, more than 11% of total US manufacturing energy expenditures. Of this amount, about $1.7 billion was spent by the lumber and wood products industry.

Literature Review

Not much literature has been cited in the area of energy management in the wood manufacturing industry especially under SIC 24 (NAICS 113, 321, 333, 337, 339). There are some publications in reference to energy savings in the pulp and paper and forest products industry. Various challenges posed by the application of energy efficient motors in highly motor intensive industries such as petrochemical, pulp and paper and food processing is discussed in Horton (1994). A survey of characteristics of different belt types, with a particular emphasis on their energy efficiency, cost effectiveness and field of application is done in De Ameida & Steve (1995). Use of premium efficiency motors in pulp and paper industry and the resulting savings are discussed by Prestil & Wroblewski (1996). The use of MotorMaster+™ in the pulp and paper and other industries to evaluate and select motors for energy efficiency and lowest life cycle cost has been described in McCoy, Rooks & Tutterow (1997). The use of research in the field of automatic inspection of wood, particularly focusing on computer vision techniques for improving productivity and reducing waste is discussed in Truong Pham & Alcock (1998). Various recommendations made during IAC assessments of over 200 pulp and paper industries are discussed by Dunning & Todd (1998).

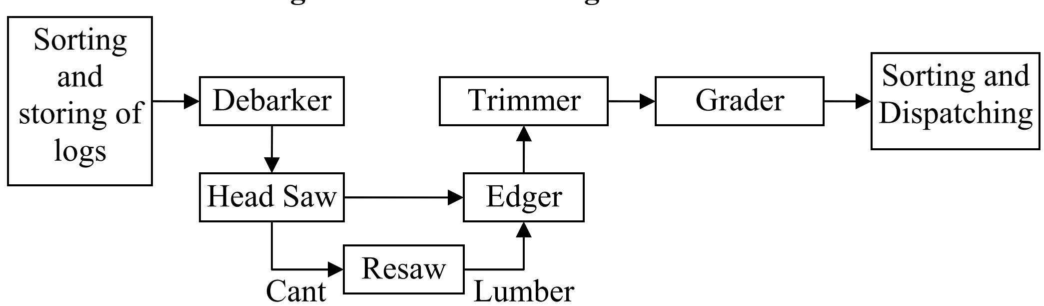
Site Visits to Wood Processing Facilities in West Virginia

The wood products industry is of growing importance to West Virginia's economy. With 11.6 million acres (1 acre = 4,046.825 sq. meter) of timberland and 75 billion board feet of inventory, the forest resources of West Virginia seem endless (WV Bureau of Commerce, 2001).

The site visits to the wood processing facilities in the State of West Virginia yielded important information about the energy utilization and production parameters. A brief description of the manufacturing process for the various facilities is provided herein. Specific information such as the facility location, average daily production, number of employees, and their weekly operating schedule is provided in Table 1. It is interesting to note that the average cost per MMBtu of electricity ranged from $14.13 (¢4.82/kWh) to as high as $23.18 (¢7.91/kWh). The load factors for the facilities were on the low side in general. It is observed that the major component of the electrical load in these facilities is contributed by electric motors (Mate 2002).

The essential operations in the manufacture of lumber are (1) breakdown of the log into boards or timber; (2) cutting the boards or timbers lengthwise in a ripping or edging operation with the objective of removing wane, improving the grade, or dimensioning to width; and (3) cutting the boards across the grain in a cross cutting or trimming operation for the purpose of removing defects, improving the grade, or dimensioning to length. A detailed flow chart of typical sawmill operations is shown in Figure 1.

Figure 1. Manufacturing Process Flow



The facilities have been given an alphabetical notation to preserve confidentiality. Facilities A, B, and C produce quality wood boards from logs using the basic sawmill operations. The manufacturing processes adopted in these facilities are similar. The principal product of facility D is rough lumber. The only difference in the manufacturing process for this plant is that a portion of the graded lumber is shipped directly to the customer and the rest go to the kiln for drying and is graded and shipped. Facility E produces Saw Lumber. Apart from sawmill operations, this plant produces pellet fuel by extruding sawdust (generated from the lumber mill and purchased saw dust) into small pellets. The final products are then inspected, packaged, and shipped. Facility F produces rough saw and kiln dried lumber. The manufacturing process is very similar to that of facility D. Facility G produces special treated industrial lumber. In this plant, the stacked logs are air dried in a steam kiln before they are treated chemically for protection. The product is subjected to a series of pressure and vacuum treatments depending on its moisture content. After treatment, some machining, such as drilling, is done if required, and then the material is packed and shipped. Facility H produces furniture grade lumber from logs. The manufacturing process for this facility is similar to that of Facility D. Facility I produces lumber using sawmill operations. The palletized lumber is shipped directly to another facility for drying.

Comparison Matrix for the Facilities Visited

A comparison of the various parameters measured and analyzed during the assessment is sought to get a better insight into the operations of each facility with a focus on energy consumption and EEM. Specific energy consumption indicators are calculated for each plant. The comparison matrix can be seen on Table 1.

General Information

Different parameters were compared regarding general information of facilities (Table 1). Most of the plants operate for one or two shifts. It was observed that the average annual production of lumber in mbf (1,000 board feet) was very high for plants E, F, G and H. These plants had very high capacity and large product variety.

Table 1. Comparison of Plant Characteristics

FACILITIES	A	B	C	D	E	F	G	H	I
GENERAL INFORMATION									
Annual Production(mbf)	9,100	4,810	4,680	6,000	27,500	20,400	13,000	13,000	7,280
# of employees	75	60	60	91	53	185	65	55	24
Shift Operation	1	2	2	2	2	1	2	2	1
UTILITY BILL ANALYSIS									
kW Demand/yr	4,077	5,303	5,096	9,526	14,677	28,081	7,017	6,229	5,513
kWh Usage/yr	842,000	1,787,904	1,892,352	3,962,400	5,918,400	11,469,248	1,119,966	2,185,920	927,168
Demand Cost ($/yr)	38,537	-	-	84,793	111,648	234,232	-	-	-
Usage Cost ($/yr)	23,584	100,364	104,832	110,605	112,927	321,253	90,707	122,816	66,422
Elec. Charge ($/yr)	63,765	100,364	104,832	191,437	227,335	541,199	88,620	118,971	68,534
Load Factor	0.28	0.47	0.52	0.58	0.54	0.56	0.22	0.49	0.234
Average MMBtu Cost ($/MMBtu)	22.18	16.45	16.23	14.13	11.25	13.83	23.18	15.95	21.66
Energy Usage/ mbf of production (kWh/mbf)	92.53	371.71	404.35	660.40	215.21	562.22	86.15	168.15	127.36

Utility Parameters

The various parameters used are utility rate schedule, kW demand, kWh usage, total electricity charges, demand as a percent of the total electrical costs, the load factor, the power factor correction and the average MMBtu cost for the facility. Some of the facilities were charged based on the usage only and did not pay for demand cost. It is observed that in general load factor depends on the number of operating shifts for the plant. The difference between the maximum and the average demand and the difference between the maximum and minimum demand provides information on the possibility of leveling the load curve around the average. In general, the plants maintained a very good power factor and there were no or limited power factor penalties.

Demand Sensitivity Analysis

A detailed analysis was performed for all the plants except facility G where sufficient data was not available. Motor load test was performed for plants G, H, and I. The analysis of motors was performed using MotorMaster+™ software (USDOE). Also cog belt replacement analysis was performed for all the plants except plant C.

Specific Energy Consumption Parameters

Ratio of parameters such as kW demand, energy usage kWh, usage cost and total electricity cost to mbf of production were used to compare the plants' performance. All the parameters across all the plants A to I are discussed in the following sections.

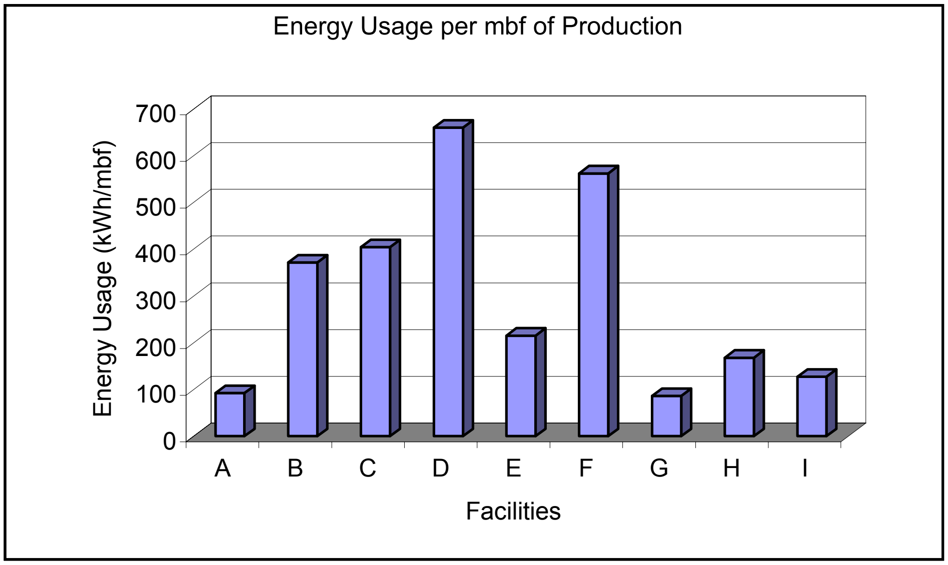
Average MMBtu Cost

It is observed that the average MMBtu cost is significant for plant A, G and I (approx. $22/MMBtu as compared to $17/MMBtu for all other plants). The total utility cost for plant A had a large demand component because the demand cost was distributed only over a one-shift operation as opposed to two or three shifts. Plant G had a treatment plant and had a different product as compared to other plants. The treatment plant of this facility was the major energy consumer. There was a large demand cost for this plant and energy consumed per year was much less as compared to other plants. The average MMBtu cost of this plant was more than $20/MMBtu.

Energy Usage Per mbf of Production

This parameter is calculated by dividing the total annual energy consumed in kWh by the annual production of lumber in mbf (Figure 2). For plant A, it was a one shift operation, but it produced large volume of lumber per shift as compared to plants B and C which produced less but consumed more kWh. This shows that the plant A had a highly efficient operation with respect to energy consumption. Plant D had a kiln for drying along with the conventional lumber manufacturing process. As a result it consumed significant kWh energy as compared to other plants. The energy usage per mbf of production was very high. Plant F had 16 kilns and 14 dehumidifiers in addition to the conventional lumber manufacturing process. As a result it consumed a significant amount of kWh per year but the value of energy usage is lower. Plant G had a different process and therefore its value cannot be compared with the other plants.

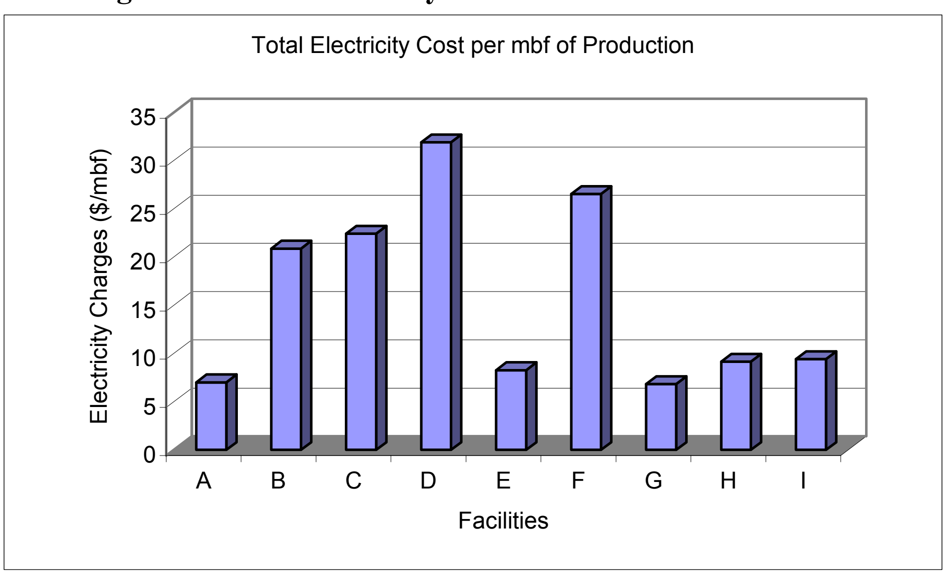
Figure 2. Energy Usage Per mbf for Plants A to I



Total Electricity Cost Per mbf of Production

This parameter is obtained by dividing the total electricity cost of the facility by the annual mbf of lumber production. It is observed that the total electricity cost per mbf of production has almost the same pattern as the usage cost per mbf of production for all the plants (Figure 3).

Figure 3. Total Electricity Cost Per mbf for Plants A to I



Usage Cost Per mbf of Production

This parameter is obtained by dividing the usage cost of electricity in dollar by the total annual production of lumber (mbf) for the facility. It depends on the energy usage plot in Figure 2. If the energy usage values of kWh in the Figure 2 are multiplied by the $/kWh cost or the usage cost for each facility then the usage cost per mbf of production will be obtained. The variation in the values for this parameter across all the facilities can be attributed to the differences among the usage pattern and the per unit usage cost.

Energy Efficiency Measures

A total of six EEM categories were recommended as a result of the energy assessments at the wood processing facilities. The EEM were categorized with respect to compressor systems, motor systems, cogeneration, lighting, and others. The total MMBtu savings for each EEM category is reported in Table 2. From this Table it is clearly evident that the most potential in terms of energy savings are with respect to the following EEM.

1. Cogeneration
2. Motor System
3. Compressor System

Table 2. Energy Efficiency Measures (EEM)

Facility	EEM 1	EEM 2	EEM 3	EEM 4	EEM 5	EEM 6
	Compressor System	Cog Belts	Motors	Cogen.	Lighting	Other*
A	13,862	57,352	52,154	-	-	-
B	34,574	150,016	135,952	-	-	-
C	18,816	153,561	139,175	-	-	-
D	50,103	-	170,819	2,147,104	17,287	-
E	79,323	90,244	205,100	-	12,893	30,536
F	230,198	67,097	182,539	-	15,929	161,443
G	32,758	47,466	84,677	-	68,059	-
H	13,081	82,626	84,970	-	18,656	96,690
I	31,982	58,893	40,727	-	6,080	-
Total (kWh)	**504,697**	**707,255**	**1,096,113**	**2,147,104**	**138,904**	**288,669**
Average Payback (Months)	**2**	**2**	**2**	**43**	**5**	**7**

Chipper, Refrigeration, Waste Oil Burner related recommendations

The total energy savings that would result from recommendations in the wood processing facilities was 4,882,742 kWh. It should be noted that the cogeneration EEM was recommend on one facility while the other EEM were recommended in almost all of the facilities. The cogeneration opportunity was recommended due to unused boiler capacity and the need for low pressure steam in kiln systems. In the category of motor systems, the EEM focused on replacement of V belts with cogged belts, motor load sizing, and using

MotorMaster+™ software in the continuous improvement maintenance mode. The compressor systems offered opportunities with respect to reduction of operating pressure by considering the overall compressor performance characteristics that include air leaks, temperature of intake air, waste heat recovery, and the use of synthetic lubricants.

Conclusion

The wood processing facilities differ with respect to each other in terms of manufacturing processes, throughput, energy consumption, and the potential for EEM. The development of a profile for wood processing facilities will aid in identifying the potential for EEM and subsequent implementation. The development and implementation of EEM is certain to reduce operating costs in wood processing and hence enhance the competitive edge of such manufacturing enterprises.

Acknowledgement

The research reported in this paper has been funded by West Virginia Development Office (WVDO).

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