ENERGY OPTIMIZATION

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Business Impact

The rapidly rising costs of energy have once again increased the business significance of energy efficiency for chemical pulp mills. Due to wide differences in technology and age of mills, there exist wide discrepancies in energy costs. Expressed as a percentage of overall production costs, the best mills achieve energy costs below 3% whereas many poor mills exceed 15%. This broad discrepancy has the potential to eliminate the normal profit margins in our industry. Fortunately for kraft pulp mills, the rising cost of energy has far less impact than other pulping processes when good technology and practices are employed. *Figure 1* illustrates the advantages and trade-offs of the chemical pulping process versus the thermal mechanical pulping (TMP) process. Historically, the TMP process has been favoured due to its much higher yield and lower wood cost. However, with today's rapidly escalating electric power costs, the wood plus energy costs of TMP are now approximately the same as kraft softwood. Low cost hardwood regions can produce high quality fibre for far less with the kraft process than the TMP process.

Wood & Energy Costs	NBSK	BEK	TMP
Wood Consumption ODMT / ADMT	2.15	1.85	.95
Purchased Electric Power Consumption MWH / ADMT	0	0	2.5
Wood Cost	$215	$111	$95
Energy Cost	25	25	150
SW Chips $100/ODMT Eucalyptus $ 60/ODMT Purchased Power $ 60/MWH	240	136	245

Figure 1

Mill to Mill Differences

The differences in energy consumption between kraft mills are driven by 4 key factors. These factors are: direct steam batched digesters versus modern continuous or super batch cooking systems; direct contact evaporator (DCE) recovery boilers versus high solids extended economizer units; limited heat recovery systems versus extensive heat recovery systems and 600 psig steam cycles versus 1200 psig steam cycles. *Figure 2* highlights various aspects of the energy differences resulting from these key factors. First of all, the total steam requirements for the process will vary from a high of 30 Million BTU's per ADMT down to a low of 20 Million BTU's per ADMT. Since a modern high solids extended economizer recovery furnace can produce a net of 17 Million BTU's per ADMT versus 12 Million BTU's per ADMT in an older DCE unit, there results a tremendous difference in the process steam requirement to be produced by a power boiler. These requirements vary from a low of 3 Million BTU's per ADMT to a high of 18 Million BTU's per ADMT. This compounding effect of process steam usage coupled with recovery boiler steam generation accounts for the wide differences of fossil fuel usage seen in the industry. At the same time, there remain substantial differences in electric power consumption in the industry. Excluding electricity used for on-site chemical production, total electrical power usage varies between 700 and 1000 KWH per ADMT. Those mills with the right combination are more than self sufficient in electrical power generation while those with lower pressure steam cycles and high consumption achieve 70% or less self sufficiency.

	High Energy Consumers	Low Energy Consumers
Total Steam MMBTU / ADMT	30	20
Recovery Steam MMBTU / ADMT	12	17
Power Boiler Steam MMBTU / ADMT	18	3
Total Electric Power Consumption MWH / ADMT	1.0	0.7
% Self Generated	70	105

Figure 2

Heat Recovery Impact

In order to understand the importance of effective heat recovery systems in energy optimization, it is essential to understand the global heat balance of a typical kraft mill. If we draw the boundaries of the balance at the initial inputs and final outputs, as illustrated in *Figure 3*, we see that the majority of the energy input to the mill from the wood dissolved in the black liquor and bark or other fuel burned in the power boilers and lime kilns ends up heating the incoming water supply and being discharged with the effluent. Simply put, pulp mills are giant water heaters. Since a great deal of this energy transfer occurs at relatively low temperatures – i.e., below 200°F, it is possible to provide much of this energy from recovered low grade energy. In fact, well designed and operated kraft mills use virtually no steam to heat either air or water below 200°F. If secondary heat recovery is not employed, process steam demand can increase up to 10 Million BTU's per ADMT in colder climates.

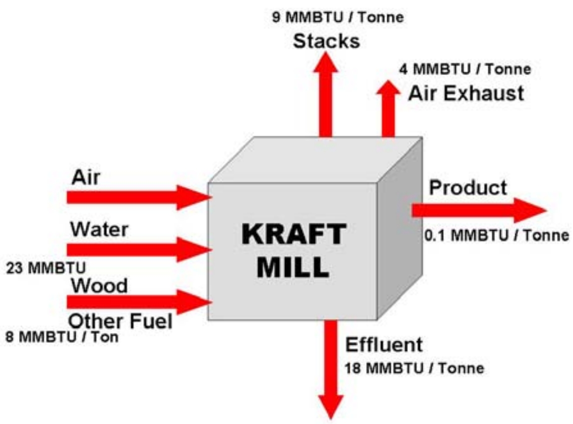

Figure 3

Figure 4 lists four key principles of well designed heat recovery systems. Principle 1 we have already discussed. Principle 2 is vitally important because energy available at temperatures above 150°F is ultimately far more valuable than energy at lower temperatures. Systems should be designed to stair step heat recovery to produce the maximum volume of high temperature water. An example of this would be to take warm water from an evaporator or turbine generator condenser and supply it as cooling water to a digester heat recovery system thereby producing twice the volume of high temperature water versus supplying the digester system directly with cold process water. It is possible to go so far a three-stage system using warm water from an evaporator, 150° water from a flue gas scrubber and 200° vapours from a digester flash system to produce very large volumes of high temperature water. Principle 3 states the importance of providing system diversity in heat recovery. It is unwise to depend on one source to provide energy to another single user. Just as electrical utilities pool the power generation from many plants, and then distribute to wide number of users, so hot and warm water systems should collect the production from various sources within the plant and then distribute as central utilities. This provides a much higher level of reliability than point to point strategies. Principle 4 is often overlooked. Substantial energy is required to pre-heat building make-up and combustion air for kraft mills. This heat can be very economically provided by circulating glycol systems. The low pressure steam freed up in this way can be diverted to a turbine generator condenser for higher electrical power production or need not be generated at all if the mill is burning oil or gas as its marginal fuel.

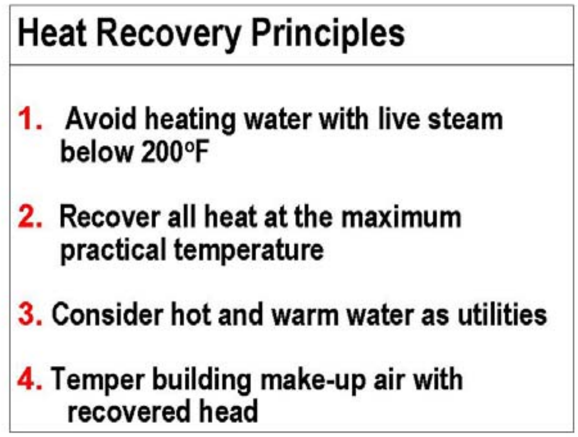

Figure 4

Recovery Boiler Impact

After heat recovery, the thermal efficiency of the recovery boiler is generally the greatest single factor in differences among mills. *Figure 5* shows the historic trend of thermal efficiency in kraft recovery boilers as technology has developed over the last 40 years. These improvements have largely resulted from the advancement of evaporator technology. Today's energy prices allow upgrades to evaporator technology in existing mills to be justified. This topic was discussed in more detail in *Recovery and Utility Management*.

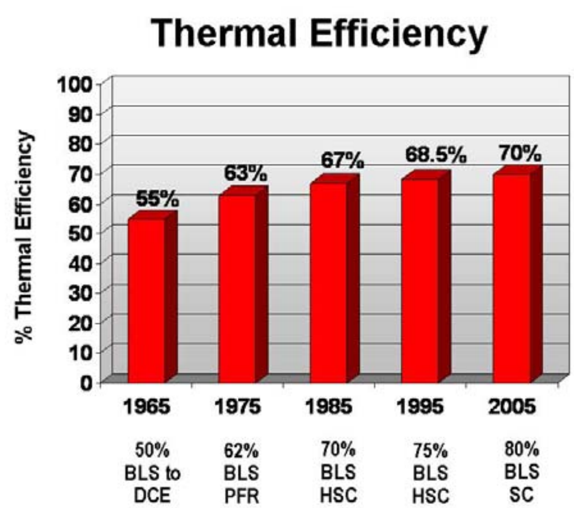

Figure 5

Steam Power Balance

The third key factor in mill energy efficiency is the steam power balance. Nearly all kraft mills employ steam turbine generators to produce electricity and low and medium pressure process steam. However, many mills have not fully optimized the potential power generation available. There are a number of factors which result in sub-optimal systems. Many mills still employ low efficiency one and two stage mechanical drive turbines to power large boiler fans and feedwater pumps. It is also common for mills to outgrow their original turbine generators. As pulp production and steam production increase, the steam turbine coupled to the generator is unable to accept as throttle flow the entire output of the recovery boiler and the power boiler. This results in high pressure steam being reduced for process use through pressure reducing valves (PRV). As well, in many cases, process loads have been shifted from low pressure steam to medium steam to increase capacity.

Returning the steam power balance to an optimum position requires long-term strategic thinking. It is much like piecing together a puzzle. Advances over the last 15 years in steam turbine design allow many older units to be rebuilt for much higher throttle flow and horsepower. Modifications to the steam path can also change the ratios of medium and low pressure extractions. It is also possible for many older generators to be re-wound to allow much higher power output in the same physical sized generator. The broad objective of steam power balance improvements is to increase the flow of high pressure steam through the high efficiency turbine connected to the electrical generator and reduce steam flows through low efficiency mechanical drive turbines or zero efficiency pressure reducing stations. The results of re-directing high pressure steam in this way can be dramatic. Most one-stage and two-stage mechanical drive turbines have thermodynamic efficiencies of 20% - 40%. Current design medium sized steam turbines have thermodynamic efficiencies of greater than 80%. Therefore, between two and four times the useful energy can be produced utilizing the same high pressure steam flow. This is, of course, a multi-step process involving replacement of the mechanical drive turbine with a high efficiency electric motor and upgrading the steam turbine generator set to accept additional high pressure throttle flow. The ability to evaluate these process changes depends upon a good steam flow diagram for the mill and the ability to use a Mollier diagram.

Unit Process Efficiency

The last major factor in energy efficiency is the design efficiency of individual unit processes. Implementing changes to cooking, bleaching, evaporization and kiln technologies is usually expensive and difficult to justify. These changes are normally made in conjunction with major mill rebuilds or expansions. However, some upgrades can be justified based on energy efficiency. As mentioned previously, the easiest economic case to make is generally for evaporator improvements. It is also possible, with some long-term thinking, to make incremental improvements to lime kiln thermal efficiencies by increasing mud feed solids and upgrading refractory linings.

Mill Evaluation

In evaluating opportunities for improvements in an existing facility, there are two key areas to investigate. The most cost effective upgrades are usually available in heat recovery improvements. The first step is a careful flow balance for warm and hot water producers and users. Once this has been complete, it is generally possible to make substantial energy savings by increasing heat recovery and restructuring the flow pattern. Remember, the bench mark is no live steam for heating air or water below 200°F. The second key area is the steam power balance. All mechanical drive turbine and PRV steam flows should be identified. Once this is complete, it is possible to make an accurate estimation of the additional electrical generation potential. With careful planning, upgrades to the existing turbine generator set can be incorporated in the plan for the next major overall.

Mill Results

Utilizing the approach outlined in this paper, Irving Pulp & Paper has made dramatic reductions in both its fossil fuel and purchased electric power consumptions. *Figures 6 and 7* show the trend for fossil fuel and electric power purchases over the last fifteen years. Beginning in 1993, a long term plan was developed to improve energy efficiency. The principal projects undertaken are listed in *Table 1.* The initial large drop in fossil fuel consumption between 1994 and 1995 resulted from low cost improvements in the secondary heat recovery system. These improvements resulted in dramatically less steam usage in the bleach plant and for boiler feedwater heating in the deareators. The second major reduction in fossil fuel consumption between 1996 and 1997 was a result of a major evaporator upgrade and increasing the black liquor solids fired in the recovery boiler to 72%. Further improvements occurred through system optimization and rebuilds of both lime kilns. The purchased electric power consumption increased significantly between 1994 and 1997 due to the installation of the new brownstock washing and oxygen delignification system, the reduction in condensing power produced from fuel oil which was non-economic, and very low reliability of the two turbine generator sets. In 2000, the steam power balance plan was implemented during the scheduled overhaul of No. 2 turbine generator. In addition to dramatically improved reliability, the unit was upgraded from 10.5 to 17.5 megawatt capability. At the same time, a number of mechanical drive turbines were replaced with electric motors. The second turbine generator set was rebuilt and upgraded the following year, increasing its capacity from 12.5 to 15.5 megawatts. During this overhaul and upgrade, the steam path was modified to accept higher throttle flow and increase 50 psig extraction capacity. This program has allowed purchased power usage to be reduced dramatically with no increase in fossil fuel consumption. Over the time span of this entire program, steam generated from bark in the power boiler has increased only modestly and the total mill process steam load is less than it was in 1993 in spite of 20% higher pulp production rates.

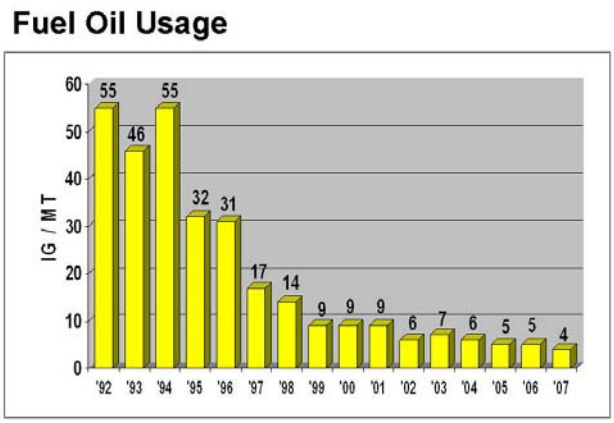

Figure 6

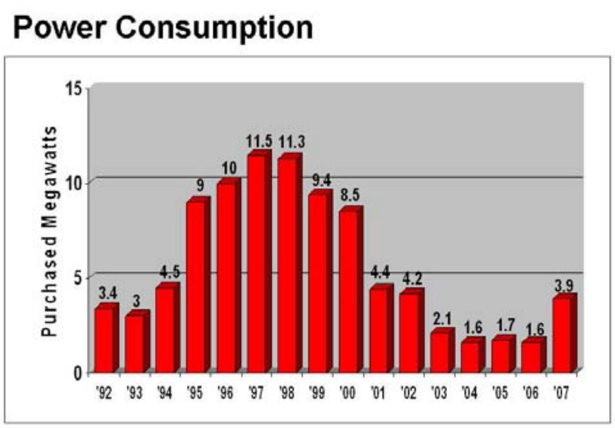

Figure 7

Conclusion

Understanding the key factors controlling kraft mill energy efficiency and careful strategic planning can result in achieving very competitive energy costs even in older mills. These efforts require extensive process knowledge and management commitment to long term excellence. Working together, great results can be achieved.

Table 1 **PRINCIPAL PROJECTS**

Stopped Blowing 3 Soot Blowers - Reduced to Two
Increased Liquor Solids to 66% • Installed HPHW Air Heater
Heat Recovery System Improvements • utilized warm water for cooling water supply to digester blow heat recovery • created high temp hot water system for bleach plant • warm water supply to demineralizers • supplied 150°F hot water to pulp dryers • increased BFW heating temp set point
Rebuilt both Lime Kilns • new pre-coat filters • new refractory • new chain sections • new burners
Increased Recovery Boiler BLS to 72% • constructed HSC • upgraded 3° air system • replaced steam drum internals
Replaced PB FD Fan MD Turbine w/ Electric Motor
Installed $Cl0_2$ Pre Heater and Chilled Water Pre Cooler
Upgraded Evaporator System • 5 → 6 effect • condensate segregation • steam stripped w/ 35 psig steam regenerator for heat recovery • lowered DA operating pressure to 30 psig
Steam Power Optimization • replaced RF FD Fan MD Turbine w/ motor • connected PB and RF feedwater systems • replaced MD turbines on feedwater system w/ electric motors
Upgraded #2 TG • new turbine steam path • rewound stator • installed Mark VI governor system • 10.5 → 17.5 MWe
Upgraded #3 TG • Mark VI governor system • re-tubed condenser • increased HP section flow capability • 12.5 → 15.5 MWe
Converted RF Steam Coil Airheater to 50 psig Steam Supply