Economics and feasibility of a greenfield cereal straw market pulp mill

It’s possible, but it would take some creative project development

By A. Shrinath, U. Tschirner and S. Ramaswamy

Abstract: KBR (formerly Kellogg Brown & Root) carried out a feasibility study for the University of Minnesota for a greenfield cereal straw market pulp mill in Minnesota. Two processes were evaluated: (1) a soda-AQ process with an ECF bleaching sequence, and (2) an ethanol pulping process with a TCF bleaching sequence. Process concepts were developed for each of these processes based on technology evaluations for the major areas. Order-of-magnitude capital cost estimates and manufacturing cost estimates were developed, and financial analyses were carried out to determine the economics of the processes.

Numerous countries around the world utilize non-woody plant materials for pulp and paper production, mainly because of a lack of forest resources to support sustained production of pulp and paper. It has been projected that the increase in world population, along with growth in the standard of living and paper consumption in many developing countries, will require a considerable increase in paper production, which in turn will put increasing pressure on the supply of wood fibre [1,2]. The growth in the standard of living and population will also result in increased competition from the lumber industry for good quality wood.

Anticipation of these changes is leading to a number of groups in the West to pay more attention to the feasibility of utilization of alternate non-wood fibre raw materials for the production of pulp and paper.

The University of Minnesota, in association with other entities in the state of Minnesota, has been investigating the potential for a pulp mill based on cereal straw. The state of Minnesota has a considerable resource base in wheat and barley straw. The University conducted a prefeasibility study to determine actual quantities of straw available in various counties in Minnesota, and came to the conclusion that there was an adequate resource base to support a pulp mill. A preliminary assessment of water and power availability, availability of labour, road and rail access and proximity to paper mills was carried out for the counties with the straw resource base, and the most promising counties were identified. Details of the prefeasibility study are beyond the scope of this paper. Suffice it to say that the University determined that certain counties had the raw material base, and the infrastructure, to support a pulp mill, at which point the University contracted with KBR to carry out an engineering feasibility study for a greenfield cereal straw pulp mill.

Objectives of Study

The main objective of the engineering study carried out by KBR was to develop order-of-magnitude (±25% accuracy) capital cost estimates, and operating cost estimates, for selected process concepts, and to carry out financial analyses to determine the economic viability of such a mill. The details of all these activities are beyond the scope of this paper, and items that are pertinent to some extent will be briefly addressed.

The basis for the mill design was largely founded on the laboratory and pilot trial work conducted by the University of Minnesota. The bleach sequences used for the cost estimates were essentially those that were evaluated by the University, with consideration of alternative sequences being beyond the scope of the study. Generally, straw needs to be pre-processed to remove leaves and nodes, which have the highest silica content and very little cellulosic content [3]. However, extensive pre-processing of straw was not included in the scope, since the straw received for the trial work was fairly clean with uniform, cut straw chips providing good cooking yields and acceptable screen losses.

Selection of Mill Capacity

Based on laboratory and pilot pulping and bleaching trials conducted by the University, design criteria were established for the mill design. These included shrinkages, losses in the fibreline, and the cooking yield, which were used to calculate the straw requirements for different production capacities.

The calculated straw requirement was compared with the straw availability within a 30-mile radius in the most promising counties. A 30-mile radius was chosen as the optimum radius for supply from a transportation and availability standpoint.

The conclusion of this analysis was that the selected counties have a sufficient supply of straw to support a pulp mill with a bleached production
capacity of 250 oven-dry short tons/day (average rate). This was picked as the target capacity for the mill.

**PROCESS DESCRIPTION**

A brief description of the soda-AQ process is provided below.

**Fibrefine:** The soda-AQ fibrefine is depicted as a block diagram in Fig. 1. Bales of straw are dewired, then washed in a hydro-pulper, and cleaned to remove sand and debris, prior to being conveyed to the digesters for cooking. Cooking is to be carried out in two lines of horizontal continuous digesters. Brownstock washing will be accomplished on twin-wash presses with four wash zones ahead of a press zone.

Pulp will be screened in a three-stage closed pressure screening system without intermediate tanks. Rejects from the final stage will be drained in an inclined rejects drainer and sent to landfill. Accepted stock is sent to a pulp thickener, where it is thickened to 12% consistency prior to being sent to storage in the unbleached high-density storage chest.

Pulp will be bleached to 85 ISO brightness in a three-stage D-E-D sequence. All bleach washers will be drum washers. Bleached pulp will be stored in a bleached high-density storage chest. Vents from the D0 and D1 towers and washers will be collected and routed to a scrubber system for removal of ClO2 emissions.

**Black Liquor Desilication:** Weak black liquor will be desilicated prior to evaporation. The principle behind the desilication concept is to lower the pH of black liquor by saturating it with carbon dioxide, which precipitates the silicate ions in the alkaline black liquor as silica [4]. Use of carbon dioxide instead of a mineral acid for lowering the pH allows for selective crystallization and removal of silica without precipitation of lignin [5,6].

**Evaporation/Chemical Recovery/Recausticizing:** Desilicated weak black liquor at 8 to 10% solids is sent to a five-effect evaporation system, where it is concentrated to 35% solids. Concentrated black liquor at 35% solids is fed to a fluidized bed chemical-recovery system.

Granular sodium carbonate product withdrawn from the bed is cooled in a product cooler prior to being sent for recausticizing.

Hot gases from the reactor, after mixing with warm air from the product cooler, go to a waste heat recovery boiler after passing through a hot gas cyclone. The flue gas is sent to a dry electrostatic precipitator, and then discharged to atmosphere through a stack.

Sodium carbonate from the recovery system is sent to a traditional recausticizing/lime kiln system to regenerate sodium hydroxide and generate reburnt lime.

**Other Areas:** Stock from the bleached high-density storage chest will be pumped to stock preparation and the pulp machine. Two options were considered for pulp drying: an air-flat dryer and a flash dryer. Cost estimates were developed for both options. Other areas included in the mill scope of facilities are bale cutting and finishing, power boiler, effluent treatment and raw water treatment.

**COST ESTIMATES**

Capital and operating cost estimates for the soda-AQ process were developed for two options: one with an air-float dryer and one with a flash dryer.

**Operating Cost Estimates:** Operating cost estimates were prepared using the specific consumptions of utilities and chemicals as determined from mass and energy balances, and from vendor quotes. Unit costs for straw delivered to the mill site were based on a combination of KBR historical data from past projects and data from the University’s prefeasibility study. Chemical costs used were from a combination of data from KBR’s database and the Chemical Marketing Reporter [7]. Unit costs for natural gas and power are quite volatile at present. Values used are based on historical pricing trends and industry projections. Other costs, such as for permitting and labour are based on the KBR database of project histories.

Two sets of operating costs were calculated: a Base Case and a Best Case. The Best Case scenario was based on the lowest unit cost of straw considered possible, and lower straw consumption due to lower screening losses. Table I summarizes the operating costs for the two cases.

**Capital Cost Estimates:** Capital cost estimates, also referred to as Total Installed Cost (TIC) estimates, were developed using priced equipment lists as the basis. Equipment prices were based on vendor quotations for the most part (approx. 80%), and complemented by pricing from KBR’s database of historical projects (approx. 20%).

The capital cost estimates are modelled estimates, based on KBR project models from actual construction projects, with suitable adjustments where necessary for specific project conditions. The estimates have an accuracy range of ±25%. The all-in construction wage rates for Minnesota were calculated using Gulf Coast base wage rates, to which factors for (a) premium pay for a 50-hour week (b) productivity considerations, such as cold weather working conditions and union labour rules in the North (c) construction equipment and (d) field indirects were applied.

The cost estimates do not include items such as escalation, client costs and training costs. However, in carrying out the financial analyses, costs for these items have been added to the TIC estimates to arrive at Total Project Costs. Further, it is important to note that the capital cost estimates do not include additional costs to place a client-sponsored Construction Management team on site to oversee the construction of the project. The costs included in the estimate cover a single
source General Contractor to execute and implement the work.

Table II summarizes the total installed costs for the two cases.

### FINANCIAL ANALYSIS

Financial models were developed for the two soda-AQ cases: (1) Soda-AQ Air-float Dryer Option, and (2) Soda-AQ Flash Dryer Option. The results of the financial models are summarized in Table III. The results indicate that both options have a very poor Internal Rate of Return, and will not be able to attain commercial financing in their present state. Typical domestic debt-financed projects require an Internal Rate of Return (IRR) of 15% (post-tax, leveraged) as a minimum, with a Debt Service Coverage Ratio (DSCR) of around 1.25-1.30, to successfully attain financing.

To better understand the effects that changes in certain costs would have on the project returns, sensitivity analyses were carried out on each scenario. These tests were based on capital expenditure, revenue, pulp price and operational cost levels varying between 20% below, and 20% above, current values. Figures 2 and 3 illustrate the impact of these changes on the rate of return. A 20% change in these factors does not appear to significantly shift the IRR towards the 15% level required for financing.

Pulp selling price and straw raw material cost figures are strongly influenced by market conditions, with the owner of the mill having little leeway in influencing them. On the other hand, there is a greater opportunity to favourably shift capital and operating cost figures in a direction that would enhance the rate of return. In order to reach the minimum threshold for attainable financing, the TIC and/or the operating cost must be reduced. As part of this study, a further analysis was carried out to examine how much the TIC, and thence the Total Project Cost, would need to be reduced, while keeping the operating cost the same, to attain a minimum of 15% IRR (post-tax). Table IV summarizes the results of this analysis for the two cases.

### DISCUSSION

As is clear from the cost estimates and financial analyses described above, it is not economical to build and operate a completely self-contained pulp mill of this scale. This does not really come as any surprise, considering that most small pulp mills of comparable scale that are commercially operating around the world do not have a number of the support facilities, such as effluent treatment and chemical recovery, which have been included in the scope of facilities for this study. The intent behind including all the mill areas in the scope of facilities for this study was to develop a baseline for the cost and economics.

Having done that, and having concluded that it is not economically attrac-
tive to include all the mill areas in the scope, the task at hand is to determine how the TIC can be reduced to the levels indicated in Table IV that is required to attain the minimum rate of return required for financing.

Let us consider the soda-AQ air-float dryer option as an example. Table V below is a rough breakdown, by mill area, of the TIC for the soda-AQ air-float dryer option.

As indicated in Table IV, the TIC for the soda-AQ air-float dryer case needs to be reduced to $119 million to achieve an IRR of 15%. Looking at the breakdown in Table V, this would require elimination of a number of mill areas from the mill scope. One way to accomplish this is to eliminate the following areas:

1. Desilication/evaps;
2. Chemical recovery;
3. Recausticizing/lime kiln;
4. Effluent treatment;
5. Stock preparation; and

It should be pointed out that this is only one of the approaches. Another approach may be to eliminate the power boiler and purchase steam, and to retain stock prep and a wet lap machine. Elimination of the areas suggested above would result in the revised TIC breakdown shown in Table VI.

But what is the significance of these changes? What does the elimination of these mill areas mean in terms of the mill design?

Desilication/evaps/Chemical Recovery and Recausticizing/Lime Kiln: Elimination of these areas would require the straw pulp mill to be located adjacent to an existing pulp mill to which the black liquor can be sold for processing, and from which soda-AQ liquor can be obtained for cooking. Alternatively, caustic can be purchased and the soda-AQ liquor can be synthesized.

Stock Prep and Drying/Cutting/Baling: Elimination of these mill areas implies that pulp would have to be sold in slush form. This would require the end-user paper mill to be located adjacent to the straw pulp mill, since it is not economical to transport slush pulp over long distances. An alternate option may be to have a wet lap machine, which would increase the TIC somewhat, but probably still within reasonable limits for an attractive IRR, since the cost for stock preparation and the machine would need to be included. However, it is not economical to ship wet lap pulp over large distances, and the end-user paper mills would have to be within a reasonable radius, perhaps 50 to 100 miles, of the straw pulp mill.

Effluent Treatment: Elimination of this area would require discharge of effluent either to an adjacent pulp mill’s effluent treatment system, or to a publicly owned treatment works (POTW) which may need to be upgraded and modified.

Along these lines, a similar analysis can be carried out for the soda-AQ flash dryer option.

In addition to reduction of capital cost, other approaches to enhance the economic feasibility of the project should also be explored. These include options to reduce the operating cost, and offtake agreements between the end-user paper mills and the straw pulp mill. Options to reduce the operating cost include consideration of alternative bleach sequences with lower chemical consumption, negotiations with straw suppliers on the delivered price of straw, and price negotiations for the supply of power, steam, and chemicals.

CONCLUSIONS

Following is a summary of the main findings from the straw pulp mill feasibility study:

1. A number of counties in Minnesota have the required straw supply, and other infrastructure, to support a small-scale pulp mill.
2. There is sufficient amount of straw available in these counties to support a pulp mill with a bleached production capacity of 250 oven-dry short tons/day (average rate).
3. The capital and operating cost of a mill of this scale, with all the mill areas included in its scope, are of such magnitude as to make it not economically attractive.
4. It is possible to reduce the capital cost of the mill, while keeping the operating cost fixed, to make the project financially attractive. This would require elimination of certain mill areas from the scope of the straw pulp mill. This is only possible if the straw pulp mill were located adjacent to an existing pulp mill, and either adjacent to or in close proximity to, end-use paper mills.
5. If the above approach for reduction of capital cost can be realistically pursued with pulp and paper mill owners, then as the project development initiative moves forward, options to reduce the operating cost should also be explored. These include consideration of alternative bleach sequences with lower chemical consumption, negotiations with straw suppliers on the delivered price of straw, and price negotiations for the supply of power, steam, and chemicals.

6. Creative project development and financing efforts, in association with other pulp and paper mill owners, would be required to achieve the objectives laid out above, and to make such a project an attractive proposition.

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