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Pulp Mills as Modern Biorefineries:
Positioned for Fiber, Fuels and Chemicals

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It is no secret that the pulp and paper industry is in decline in North America. According to a recent article in *Paper 360°*, total production of paper and board has dropped about 10% since peaking in 2000-2001 after decades of steady growth.[1] The economic downturn we are currently experiencing has seen more than 20 mills shut down permanently in 2009 after more than 25 closed their doors in 2008. It is reasonable to think, however, that the downturn only hastened the inevitable. Modern capacity is coming online in other parts of the world, most notably in East Asia and South America, thanks to lower costs, improving infrastructure, and increased local demand. It is difficult to imagine this trend changing anytime soon.

The biorefinery concept has been touted of late as a new concept to invigorate the established pulp and paper industry. A biorefinery converts biomass to physical products, commonly thought of as fuels and/or chemicals, and to energy. In fact, this is exactly what a pulp mill does, converting wood to fiber and generating heat and power; the pulp mill is the original biorefinery. Compared with a petroleum refinery, however, the outputs from a pulp mill are relatively limited. Petroleum refiners and the petrochemical industry they have spawned produce many more products, from high-volume commodities to high-margin specialty chemicals. This diversification presents more opportunities to produce profits and to protect against downturns in any particular market. Today's mills can benefit from similar diversification for the same reasons.

Most of the biorefinery projects currently in development are to be greenfield operations, but at least a few are being developed adjacent to or within a mill, where they enjoy several benefits. Feedstock management is amongst the most important. In contrast to agricultural residues like corn stover and purpose-grown energy crops like

[1] Patrick, K., & Ostle, G. (2010, January/February). Outlook: North America 2010. *Paper 360°* , pp. 8-11.

switchgrass that are the intended feedstock for some other biorefinery projects, the feedstock for a wood-based biorefineries is already commercially harvested and available through established markets. Mills understand the dynamics of these markets and routinely contract for supply of this feedstock, oftentimes sourcing material from lands controlled by the mill's owner. Similarly, feedstock handling on site, including inventory control and size reduction, are already practiced with wood and so do not represent significant risk to a mill considering a broader biorefinery operation.

Biorefinery technology pathways are typically categorized as biochemical or thermochemical (or a hybrid of the two), and pulp mills are already experienced with some elements of these pathways. A biochemical pathway, for example, typically requires some sort of "pretreatment" at the beginning of the process, in order to open up the biomass and perhaps also initiate hydrolysis of the hemicellulose contained within the biomass into its constituent sugars. A biorefinery pretreatment process may not be much different from the cook step in a pulping operation. On the thermochemical side, gasification has certainly received the lion's share of the attention. Gasifiers operate with limited oxygen, compared with boilers and furnaces that require excess oxygen for full combustion. However, much of the technology for equipment design is the same, including feedstock introduction, ash disposition, and general configuration. Again, these are things with which mills have much experience.

Operating mills do not need to build an entirely new process in order to add to their product mix. Within today's mills are a number of process streams that may be converted to higher value. Biological processes generally operate on sugars as a feed stock. The spent pulping liquor from sulfite mills (red liquor) contains an appreciable amount of fermentable sugars. The former Georgia-Pacific mill in Bellingham, Washington, produced ethanol through fermentation of its red liquor for more than 55 years until the mill was shut down. Today the Tembec mill in Témiscaming, Québec, produces ethanol from its red liquor. According to the company, this ethanol is further fermented to acetic acid, which supplies much of the vinegar industry in Eastern Canada.[2] For the more common kraft mills, there is opportunity to extract hemicellulose sugars from wood chips prior to pulping (Value Prior to Pulping), as advocated by the Agenda 2020 Technology Alliance. At the present, however, this remains a technology area still in development.

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[2] *Products - Chemical Products - Ethanol*. (2010). Retrieved June 1, 2010, from Tembec Inc. corporate web site: http://www.tembec.com/public/Produits/Produits-chimiques/Ethanol.html

We also consider primary pulp mill sludge, which is largely cellulose fiber too small for paper or board making, as another stream with potential value in an expanded biorefinery. The cellulose fiber requires additional treatment to hydrolyze the cellulose to fermentable sugars, but it appears today that enzyme technology is mature enough to execute that hydrolysis affordably and with high yield. Mills work to minimize the amount of primary sludge, so it may not be a large amount, but within the infrastructure of the mill and because "pretreatment" has already taken place within the pulping operation, the additional capital required for installing an operation to convert that sludge to ethanol or some other fuel or chemical will be relatively small. Thus, a good return may be obtained for even a relatively small volume of output.

The Agenda 2020 Technology Alliance has also advocated for gasifying spent pulping liquor (black liquor) into a synthesis gas for replacing natural gas elsewhere in the mill or subsequent conversion to liquid fuels and chemicals. Mills typically burn their spent liquor in a recovery boiler in order to regenerate their pulping chemicals and simultaneously generate steam and power for the mill from combustion of the lignin and hydrolyzed sugars within the liquor. If black liquor is gasified instead, the pulping chemicals can still be recovered, but much of the energy that was going into steam and power will be retained as chemical energy within the product synthesis gas, and so the mill will have to find other sources of energy for steam and power, perhaps combusting additional biomass, in order to maintain its operation. The synthesis gas needs to produce sufficient value upon conversion to make up for the cost of replacing its fuel value.

When it comes to possible products from a biorefinery, ethanol is usually at the top of the list. However, there are many other options available and perhaps multiple products might be considered. If a biological pathway is selected, fermentation can also produce butanol, organic acids, fatty acids and alcohols, and monomers for polymerization. Similarly, the synthesis gas produced in gasification can be converted to a host of products. Gasification processes to produce ammonia, Fischer-Tropsch liquids, methanol, and dimethyl ether are all currently in development. Process economics may be more favorable for some of these other products, especially when being produced at smaller volumes as an additional product for a mill rather than in the higher volumes that might be seen in a purpose-built, greenfield plant. A feasibility study is often a good first step to examine the options that might make sense.

About the Author:
Doug Dudgeon, Ph.D., has 16 years in process development and project management for the chemical and consumer products industries. He has established capability in planning and execution, leading cross-functional teams, and creating and implementing product and process innovation. Dr. Dudgeon's experience encompasses technology and site evaluation, process conceptualization and commercialization, and management of research and development programs in multiple industries, including biomass conversion to fuels and chemicals. He is an affiliate associate professor in chemical engineering at the University of Washington, where he advises on bioenergy technologies.

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