A Compelling Case for Integrated Biorefineries (Part II)

Recent DOE grant recipients choose from among several biorefinery "pathways" forward

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In part 1 of this article (*Paper 360°*, March 2008) we suggested that the forest products industry has the commercial skills and resources critical to the emerging biorefinery industry. To help sort out real opportunities from volumes of information containing far too much hope and hype, the charts on the following pages show a number of "process pathways" forward.

Pathways 1 and 2 start with biomass as the raw material, which is gasified by placing it in a receptacle with controlled and limited oxygen, and applying heat. As a result, the organic portions volatilize into a gas composed of hydrogen, carbon monoxide and carbon dioxide—called syngas.

After gas cleanup, the syngas is chemically the same as syngas derived from the gasification of

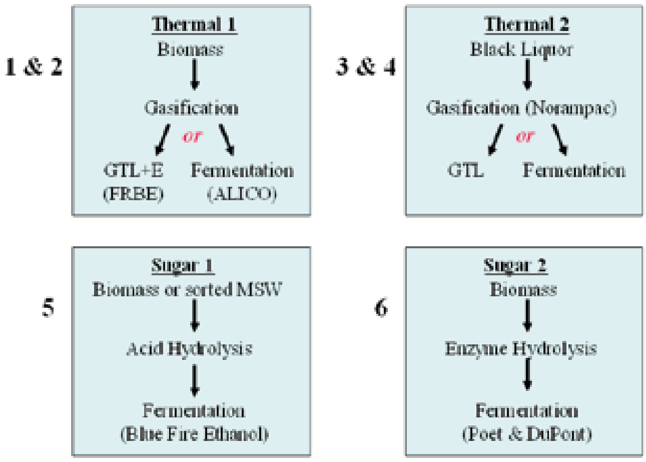

Figure 1. Pathways 1 through 6.

coal—which has been done for 50 years in South Africa. Certain gasification units can better tolerate and process mixes of biomass. This is critical when comparing pathway feedstock costs. The cost of equipment dictates that each facility will have to choose either Pathway 1 (left fork) or Pathway 2 (right fork)—but not both.

The left pathway uses a gas-to-liquid process (GTL) like a Fischer-Tropsch catalytic reactor. This produces a clear, sulfur-free, multi-molecular fluid that is chemically superior to low-sulfur crude. It can be further refined to synthetic gasoline, synthetic diesel or a variety of other synthetic products. South African Synthetic Oil Ltd (SASOL) has been doing this for 50 years with syngas from coal. The "Thermal 1" pathway has been proposed for NewPage, Wisconsin Rapids, WI, and Flambeau River Biofuels, adjacent to Flambeau River Papers in Park Falls, WI. When the "Thermal 1" pathway is adjacent to a steam host, it has two significant revenue streams: recovered heat (shown as an "E") and biofuels (shown as "GTL").

The second pathway (right fork) will ferment the syngas, making a variety of products (see B.A. Thorp and W J Frederick Jr., "Standing at a Fork in the Road," *Paper360°* June/July 2007). This pathway was chosen by ALICO in Labelle, FL.

Pathways 3 and 4 are similar to Pathways 1 and 2 except that black liquor is used as the raw material. This is a tougher application for gasifiers since black liquor is much more corrosive than biomass. Also there are difficulties drying it to the 85% solids level desired for biomass infeed. More importantly, there is a higher requirement for carbon conversion because of pulping chemical recovery. Since 2003, Norampac in Trenton, Ontario, has been successfully gasifying all of its carbonate black liquor in a TRI low-temperature "Steam Reformer" and burning the syngas in existing gas boilers. For several years, Weyerhaeuser in New Bern, NC, has been gasifying approximately 15% of its Kraft black liquor in an atmospheric, high-temperature gasifier supplied by Kvaerner-Chemrec. This unit restarted with a new vessel and refractory lining about the same time that Norampac started.

Pathway 5 is based on a sugar technology platform. This starts with biomass as the raw material. The acid hydrolysis is so powerful that sorted municipal waste can be used. The acid converts compounds like cellulose to sugars, which are subsequently fermented to ethanol or other chemicals. This process has been developed by Blue Fire Ethanol and demonstrated at a pilot plant in Japan. A full-scale plant with partial Department of Energy funding is planned for southern California. Pathway 6 typically takes a selected, uniform raw material like corn stover or wheat straw and converts the cellulose material to sugars by enzymatic hydrolysis. Subsequently, the sugars are fermented into ethanol or other chemicals. This will be done by Poet (formerly Broin Industries) and DuPont. For all process pathways, yield may be fractionally lower when both 5- and 6-carbon sugars are fermented. Neither Pathway 5 or 6 utilizes any lignin present in the raw material, so they are primarily being customized for low lignin feedstocks like MSW or energy crops like wheat straw. To date, enzyme hydrolysis has been very sensitive to the uniformity of raw material input, even water quality.

ANOTHER PATH

Pathway 7 starts with debarked pulpwood chips that are pulped with a unique AVAP™ process. The cellulose is bleached and sold as chemical-grade dissolving cellulose or market pulp,

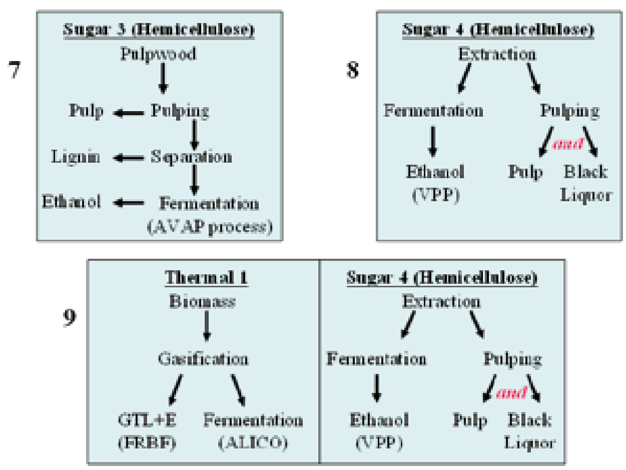

Figure 2. Pathways 7 through 9.

both of which have a higher selling price per pound then ethanol. Next, the lignin is removed from the pulping liquor and used to fuel the entire process. Finally, pulping chemicals are removed and the resulting broth is rich in monomer hemicelluloses, which are subsequently fermented to ethanol or other chemicals. This process pathway has two revenue streams and an energy cost reduction stream.

This is a good place to note a fundamental difference between some of the processes. Pathway 7 separates the biomass, which in this case is wood, into its three naturally occurring chemicals—namely lignin, cellulose and hemicellulose. Each can be sold into markets for its maximum value, illustrating the powerful concept of co-production. In Pathways 1 to 4, the heat should be recovered from all processes and sold to an adjacent steam host. This is a valuable co-product.

Pathway 8 is called value-prior-to-pulping and is under development by a consortium of paper companies, universities, DOE and USDA, and is being led by CleanTech Partners in Middleton, WI. In this pathway, wood chips are exposed to a water-based extraction phase prior to pulping in order to remove a portion of the hemicelluloses. This process must preserve both pulp yield and strength, which has only been demonstrated for hardwoods. The hemicelluloses are taken to a separate process and are fermented to ethanol or other chemicals. The chips are taken to the Kraft process, which can be operated with lower energy consumption and less load on the recovery boiler. A pilot plant has been proposed for a pulp mill in the Northeast.

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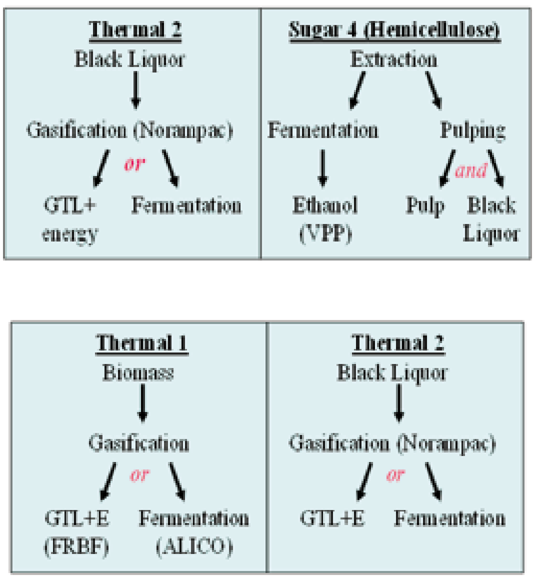

Figure 3. Pathways 10 and 11.

Pathways 9, 10 and 11 are combinations of Pathways 1 to 8, which can be economically and technically combined. Even these simple block flow diagrams demonstrate that biorefineries will be quite different from each other and far more complex than can be shown in conceptual diagrams.

Pathway 12 starts with woody biomass, which is treated with a patented separation process. The lignin is separated without being exposed to sulfur or severe oxidation conditions. This pure lignin is sold at a higher price than ethanol into markets that require purity. The remaining cellulose and hemicellulose is fermented to ethanol or other chemicals. This is another example of a process with co-products.

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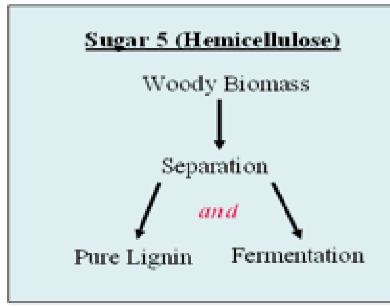

Figure 4. Pathway 12.

PREDICTIONS

Based on raw material costs, reported yields and operating cost estimates, it is possible to predict at least some of the short-term winners. Let's look at basic economics. The most common yield reported is about 80 gallons of biofuel per bone dry ton (BDT) of biomass. The most frequently used selling price for biofuel is about $2 per gallon. This gives a revenue stream of about $160 per BDT of raw material. This revenue must pay for raw material procurement, utilities, labor, marketing and debt payment. Just a few calculations will illustrate that a revenue stream of $160 per BDT leaves little or no profit margin.

Therefore, the profit can only be made when there is a unique situation of very low cost raw material (like the Blue Fire business model) or when the chosen process produces another high value product like cellulose, lignin or salable recovered heat that offsets expensive fossil fuel. It appears that the short-term winners will use pathways 1, 2, 7 and 12 or have unique raw material situations. There is far more commercial experience with the unit operations of Pathway 1. Short-term refers to biorefineries being built now or whose construction will start this decade.

One of the more promising features of the longer term chemical processes are yields exceeding 120 gallons per BDT of raw material. An example of an older chemical technology is Bio-Oil. An example of a newer emerging technology can be seen at www.Virent.com. Long-term—perhaps 7 to 10 years from now—new winners will be based on one or more of these chemical technology platforms. It appears that there will be other long-term winners, but they are likely to be based on "niche" situations. 360

(This is part 2 of a 3-part series that began in the March issue of *Paper360°* and will conclude in the May issue.)

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