Agenda 2020 analysis charts a course

BY AGENDA 2020 CTO COMMITTEE WORKING GROUP

The chief technology officers of the American Forest & Paper Association's Agenda 2020 Technology Alliance recently conducted an analysis of the most feasible and effective routes for forest products facilities in this country to add energy, biofuels and bio-based chemicals to their existing product streams.

Considering that at least 21 billion gallons of the 36 billion gallons in the new federal Renewable Fuels Standard (RFS) are to be obtained from cellulosic ethanol and other advanced biofuels, the forest products industry—and pulp and paper mills in particular—is in a unique position to help meet this national challenge while continuing its longstanding commitment to sustainability. By integrating biorefinery capacity with existing fiber processing operations, pulp and paper mills could extract far more value from wood than they currently do.

In fact, Agenda 2020 members had concluded in 2004 that the integrated approach offered a much more capital-attractive and operationally-feasible approach than a stand-alone biorefinery facility. They thus coined the term "Integrated Forest Products Biorefinery."

There are many approaches to the Integrated Forest Products Biorefinery, and the related operating and financial analyses are complex. The officers wanted to clarify key issues investors should take into account when considering integrating a thermochemical conversion process with an existing pulp and paper mill by providing an example of a possible phased approach and a summary of previously published financial studies.

This article is presented in two parts—Part 1 is focused on the various technology, operating and investment options, while Part 2, which will appear in the May 2008 *Paper360°*, looks at the financial case from several critical perspectives.

IT'S IN THE BLOOD

The Integrated Forest Products Biorefinery has several major advantages over a stand-alone facility. Pulp and paper mills are typically located near biomass resources such as forests and agricultural crop residues. They have in-place, operating infrastructures to harvest, process and store biomass, and equally as important, they have a large, existing infrastructure to ship finished products.

In the U.S. alone, pulp and paper mills use more than 120 million dry tons of wood per year, and they have access to at least an equal amount of forest residuals and even a greater amount of agricultural wastes and energy crops if needed. Most chemical pulp mills have been producing electricity and process heat from their own residuals while recovering pulping chemicals for well over a century,

Today's mills, for example, produce on the average 60% of their power from wood residuals and spent pulping liquors. They have a highly trained workforce very capable of operating energy and future biorefinery systems. From this perspective, it can be said that producing energy from biomass is "in the blood" of most pulp and paper mills.

By integrating thermochemical systems with the existing mill operation, greatly improved thermal efficiencies are achievable, new revenue streams can be generated, and operating costs can be significantly reduced. In short, integrated biorefineries are a natural fit with most pulp and paper mills.

THERMOCHEMICAL BIOREFINERY

The thermochemical approach considered in this analysis involves gasification of solid biomass and/or black liquor (spent pulping liquor) from the kraft chemical pulping process to produce syngas. Solid biomass includes forest and agriculture residues—wood unsuitable for pulping and wood residues typically left in the forest or used in power boilers, leftover residues from the harvesting of crops—and in the future, dedicated perennial energy crops. While other pulping processes are also suitable, kraft was selected because of its dominance in the industry.

Depending on the nature of the gasification process, the syngas has a low to medium energy content and consists mainly of carbon monoxide, hydrogen, carbon dioxide, water, nitrogen and various contaminants.

Although there are many ways of implementing forest biorefineries at existing pulp and paper mills, there are basically three approaches based on the type of biomass-to-syngas technology employed and the product(s) made from the syngas. With these three approaches, biomass is converted into syngas and then:

1. Combusted in a boiler or lime kiln to reduce operating costs by displacing fossil fuels.

2. Used to create new revenue streams by manufacturing and selling transportation biofuels and/or high value chemicals. Excess heat and uncovered syngas is used to co-generate heat and power and reduced operating costs by displacing fossil fuels at the mill.

3. Used to co-generate heat and power in combined cycle power plants and reduce operating costs by displacing fossil fuels at the mill and to create new revenue streams by exporting (selling) excess green power to the local grid.

Several U.S. and European studies have examined the integration of a thermochemical biorefinery with a pulp and paper mill, and they all conclude that it is an ecomomically attractive proposition. The most in-depth study done at Princeton University examined a combination of black liquor and solid biomass gasification. A European Union-sponsored study looked only at black liquor gasification and also concluded that the economics are extremely attractive. A Finnish study looked at solid biomass gasification and concluded that co-production of transportation fuels via the syngas route has the potential to significantly improve the profitability of pulp and paper mills. For references, see the link to the full report at the end of this article.

PHASED IMPLIMENTATION

The following examines how the three basic approaches can be implemented im a step-wise fashion to convert an existing pulp and paper mill to a fully integrated biorefinery—carbon neutral and energy independent—producing a number of value-added products as well as traditional paper products. This phased approach is designed to mitigate risk associated with the various technology platforms being deployed.

Phase 1 carries the least risk since much of the technology is commercially proven; Phase 2 is only considered for implementation once Phase 1 is considered successful, and Phase 3 is only considered when Phase 2 is proven to operate reliably and meet expectations.

The existing mill to be converted:

- Uses as feedstock wood chips that are produced at wood products mills and off-site chip mills
- Uses steam, electricity and chemicals to convert wood chips to cellulose and cellulose to paper products
- Provides for a portion of its energy requirements by burning black liquor and woody residual biomass, but it also ports (buys) natural gas and electricity
- Burns natural gas in boiler to produce additional process steam and in a lime kiln as part of its chemical recovery process

PHASE 1

Phase 1 has two options. In both options the feedstock used is solid biomass (forest and agricultural residues)

Option 1 of Phase 1 involves the use of a commercially-proven gasification plant to produce syngas for burning in the lime kiln, pulp dryer or boiler. Option 2 involves the addition of a syngas cooling and conditioning stage and Installation of a gas-to-liquids (GTL) plant for the manufacture of transportation fuels.

As depicted in **Figure 1,** the gasification plant in Option 1 can be relatively simple, not requiring the same level of gas cleaning and comtaminant removal as necessary for the GTL plant in Option 2.

As noted above, equipment to produce syngas (from bark and solid waste wood) as a lime kiln and/or pulp dryer fuel is commercially available, with several such gasifiers put into paper industry service in the late 1980s. Currently, two mills in Scandinavia are reportedly still running these units. Several mills have

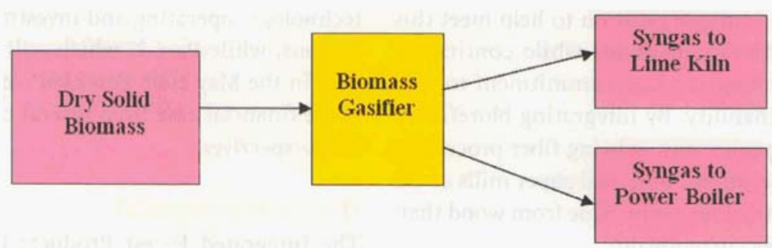

Figure 1. In the first option of a Phase 1 project, biomass is converted into syngas, which is then combusted in a lime kiln, pulp dryer, or boiler to reduce operating costs by displacing fossil fuels.

been burning syngas produced from black liquor in their boilers for a few years. Last summer a British Columbia mill announced a project to demonstrate the use of syngas (produced from solid biomass) to displace natural gas used in its lime kiln, with expecting savings of several million dollars per year and a reduction in greenhouse gas emissions of 25,000 metric tpy.

The question has been raised whether an Option 1 plant can start small, minimizing exonomic risk, and then later be modified to make biofuels and power by adding syngas cleaning and synthesis process equipment, i.e., move in two steps to an Option 2 plant. Progressing to Option 2 in this case would depend very much on the desired end goal and decisions taken in Option1.

If Option 1 is executed only as a cost-savings measure, and the lowest-cost gasification processes are selected to maximize ROI, it is unlikely that a second-step progression to Option 2 will be feasible. Such ROI-focused projects typically involve selection of an air-blown, atmospheric-pressure gasifier, with a fixed or fluidized bed producing Low Calorific Value (LCV)

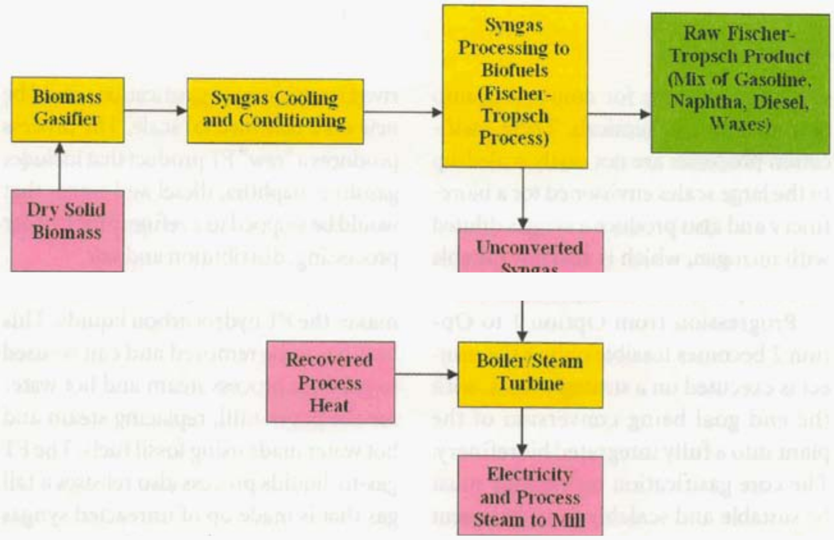

Figure 2. Conversion of solid biomass to syngas and then to Fischer-Tropsch (FT) transportation biofuels. Excess heat is used to generate combined heat ad power for the mill.

syngas unsuitable for converting into biofuels and biochemicals. These gasification processes are not easily scaled-up to the large scales envisioned for a biorefinery and also produce a syngas diluted with nitrogen, which is also not suitable for transportation fuels synthesis.

Progression from Option 1 to Option 2 becomes feasible only if the project is executed on a strategic basis, with the end goal being conversion of the plant into a fully integrated biorefinery. The core gasification technology must be suitable and acalable for subsequent production of biofuels and chemicals and must be configured so that it can be easily scaled up without making the initial investment redundant.

Option 2 (illustrated in **Figure 2**) involves the conversion of solid biomass into syngas, which passes through conventional heat recovery before being cleaned and conditioned and converted into a transportation biofuel using a Fischer-Tropsch (ET) type of GTL plant. Excess heat is used to generate combined heat and power and reduce operating costs by displacing fossil fuels at the mill.

The FT process has existed for several decades, but the application to syngas derived from biomass gasification would be new on a commercial scale. The process produces a "raw" FT product that includes gasoline, naphtha, diesel and waxes that would be shipped to a refinery for further processing, distribution and sale,

The biorefinery gives off heat as it makes the FT hydrocarbonliquids This heat has to be removed and can be used to produce process steam and hot water for the paper mill, replacing steam and hot water made using fossil fuels. The FT gas-to-liquids process also releases a tail gas that is made up of unreacted syngas and light, non-condensable hydrocarbon gases that are used in the pulp and paper mill to also replace/offset natural gas and other fuels.

Use of excess heat and tail gas to displace fossil fuels can result in significant cost reduction for the mill.

An example of this option is the recent award by the Department of Energy to the NewPage Corp. of a grant of up to US$30 million for the development, construction and operation of a 10% scale thermochemical biorefinery.

PHASE 2

In Phase 2, illustrated in **Figure 3,** the mill replaces the Tomlinson chemical rec overy boiler. The biorefinery is increased in size to process the organics in the black liquor to syngas and to recover the pulping chemicals for reuse by the pulp mill. The production of biofuels, steam and power is increased to meet the mill's needs.

Syngas from the black liquor is cleaned up and fed to the gas-to-liquids plant to produce more transportation fuels. With much of the energy in the mill's biomass residuals now going into the production of high-value transportation fuels, the mill does not produce enough steam to meet its process needs. To replace this lost steam production, additional supplies of solid biomass are fed to the biorefinery. This further increases the production of carbon neutral transportation fuels and restores the balance between the steam demands of the mill and the amount of waste heat used to produce that process steam.

With the installation of Phase 2, the mill is fossil fuel and purchased electricity independent. It is now a virtually carbon neutral manufacturing site, producing paper products and transportation fuels. This could be a particularly attractive option for many mills, particularly in the U.S., facing the imminent need and high cost to upgrade aging recovery boiler systems. Part 2 of this article will further explore the financial aspects of this option.

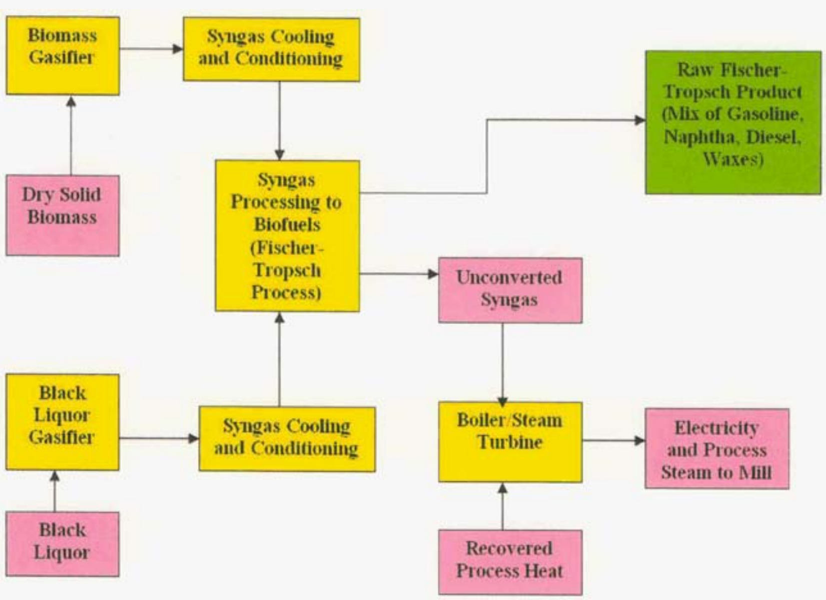

Figure 3. A gasifier is added to process the black liquor and the overall biorefinery capacity is increased.

PHASE 3

Phase 3, as illustrated in **Figure 4,** involves a further increase of biorefinery output. To do so economically, the size of the paper mill heat and energy sink must also be increased, for example by adding a combined cycle gas turbine and a steam turbine with tail gas as its fuel.

At this level the manufacturing site, i.e., the Integrated Thermochemical Forest Products Biorefinery, would be:

- Carbon neutral and purchased energy independent
- Producing pulp and paper products
- Producing renewable transportation fuels
- Exporting (selling) "green" electricity to the grid

THE BUSINESS CASE

Part 2 of this article will focus on production and financial considerations of an Integrated Thermochemical Forest Products Biorefinery and will explore capital costs and ROI issues, production yield and capital intensity comparisons, and business plans/partnership possibilities relative to the three phases or options discussed above.

Editor's Note: *Access the full report at www.tappi.org/biorefinery.*

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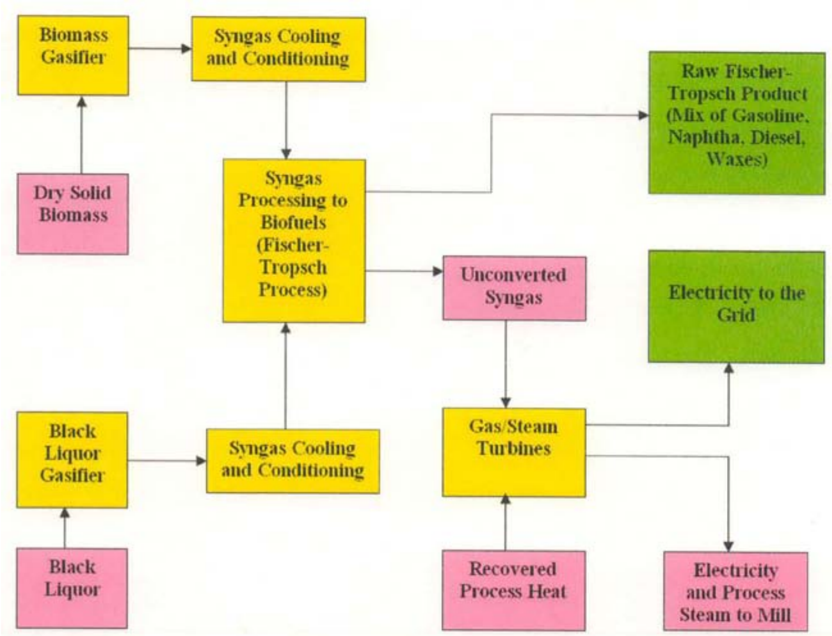

Figure 4. The mill adds a combined cycle gas turbine and a steam turbine and exports renewable fuels and green electricity to the grid.