Agenda 2020 analysis explores financial issues

BY AGENDA 2020 CTO COMMITTEE WORKING GROUP

Part 1 of this two-part article (published in the April 2008 issue of Paper360°) focused on the technology, operating and investment options for adding biorefinery capacity to existing pulp and paper mills in the U.S. Part 2 examines the financia1 case for adding such capacity.

This two-part analysis of the most feasible and effective URXWHVIor the pulp and paper and forest products industry to add energy, biofuels and bio-based chemicals to WKHLUHxsting product streams was conducted by the American Forest & Paper Association's Agenda 2020 Technology Alliance. A full, detailed presentation of this analysis will take place during the special bridge session linking TAPPI's 2008 Engineering, Pulping and Environmental Conference with its 2008 International Bioenergy and Bioproducts Conference being conducted as back-to-back events at the same venue in Portland, OR, Aug. 24-27 and Aug. 27-29, respectively.

The business case discused in this article is based on a post-2010 gasification biorefinery operation at a kraft pulp and paper mill as described in a recent report by Princeton University.[1] The reference pulp and paper mill in the Southeastern U.S. produces 1,580 dry tpd of kraft pulp using a 65/35 mix of hardwood and softwood. Its finished product is 1,900 tpd of free sheet paper. The mill's Tomlinson chemical recovery boiler is near the end of its serviceable life and in need of replacement, a situation shared by many U.S. kraft mills today.

The business case examines incremental investment in a biorefinery as an alternative to a new Tomlinson system.It looks at two biorefinery configurations, one producing dimethyl ether (DME) to be used as an LPG (propane) blend stock, and the other producing Fischer-Tropsch (FT) synthetic crude oil for refining to diesel and gasoline blendstocks at petroleum refineries.

Two energy price senarios derived from the 2006 U.S. Department of Energy Annual Energy Outlook (AEO 2006) are used—the AEO Reference scenario and a High Price scenario. In the

Reference scenario, crude oil drops from current peak levels and stabilizes in the US$45-US$55 per barrel range over the post-2010 forecast period. In the High Price (Tight Supplies) scenario, crude oil prices are projected to climb to US$90-US$95/barrel (in constant 2004 dollars). The AEO Low Price scenario, where oil returns to US$28-US$35/barrel and stays there, was not considered as it was deemed the least likely of the three scenarios.

Of course, crude oil prices are currently above the High Price scenario, hovering around US$120-US$140 per barrel. However, long-term prices are expected to moderate toward US$100 per barrel as alternative fuel production and markets develop, speculation subsides and as general demand continues to decrease under the pressures of high costs.

The Princeton BLGMF (black liquor gasification to motor fuels) designs include high temperature pressurized oxygen-blown black liquor gasification and mill-scale gas turbine combined cycles, which are more efficient in generating electricity than steam turbines cycles used in Tomlinson systems. In these case studies, the pulp and paper mill's process steam demands were met by brining in additional wood biomass to make up for the process steam deficit created by converting black liquor to motor fuels. In this respect, the Princeton case studies are analogous to Phase 2 discussed in Part 1 of this article.

Two of the Princeton cases, DMEa and FTc are discussed below. In the DMEa case, incremental woody biomass is burned directly in an existing hog fuel boiler to generate steam. In the FTc case, the woody biomass is sent to a separate pressurized oxygen-blown fulidized-bed biomass gasifier to produce additional syngas for fuel synthesis and additional combined cycle power generation from the synthesis plant tail-gas.

The DMEa product configuration employs a liquid-phase synthesis reactor, and uses only syngas from black liquor to produce DME. The final DME product has an estimated purity of 99.8%, suitable for direct blending with commercial LPG (up to 25%).

The FTc configuration employs a liquid-phase FT synthesis reactor with iron-based catalyst, using syngas from black liquor and biomass gasifiers. The raw product ("FT crude") would be transported by trucks (with heated tanks to maintain the wax fraction as a liquid) to existing petroleum refineries where it would be used as a petroleum crude substitute for processing to finished products.

BENEFITS AND COSTS

The main economic benefits of biorefining in these cases (relative to a Tomlinson boiler) include additional revenues from sale of synthetic fuels (511 tpd of DME, equal to 2,362 barrels per day petroleum equivalent or 4,757 barrels per day petroleum equivalent of FT crude), a savings of 226 tons per day of pulpwood due to increased pulp yield, and slightly lower steam use (200.1MWth versus 212.1 MWth).

This BLGCC design results in a 16% increase in lime kiln load, accommodated by using oxygen-enriched air. Besides those added costs, and since pulp and paper output remains constant, other mill variable costs such as electricity do not change, However, biorefining imposes added cost burdens, including capital investment for the biorefining systems and related operating costs.

The operating costs are mainly related to additional purchases of wood biomass (772 dry tpd used as hog fuel for the DME product configuration, or 2,981 dry tpd for biomass gasification in the FT configuration), and adjustments in purchased electricity (an increase of 64 MW in the DME configuration or reduction of 13 MW in the FT configuration).

Estimated capital investment costs (2005 dollars) are US$252 million for the DME configuration and US$465 million for the FT configuration, versus US$136.2 million for a new Tomlinson system. The internal rate of return (IRR) for the incremental capital investment is sensitive to product configuration, energy price scenario, economic incentives and capital costs. The internal rate of return is caluclated on the incremental investment (the difference between the gasification system and the Tomlinson boiler, i.e. netting out the US$136.2 million replacement cost for the Tomlinson).

The rationale was that a mill would be more likelyto considera gasification system when faced with having to replace its recovery boiler. Replacing the boiler is a necessary expense for the mill to continue operating even though there is no return for the investment and the decision as whether to select a boiler or a gasification system would be decided based on the return on the incremental capital. In the Reference scenario (US$45-US$55 per barrel), the IRR is 14% for the DME product configuration and 18% for the FT configuration. In the High Price scenario (US$90-US$95 per barrel), the IRR is 25% for the DME configuration and 28% for the FT configuration.

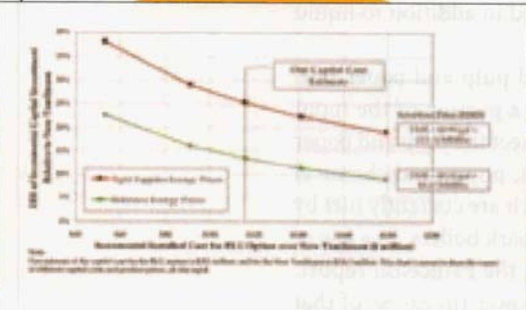


Figure 1. Allowable incremental capital cost for DMEs biorefinery (with DME sold as a LPG substitute) relative to new Tomlinson investment for different target IRR values under the two energy price scenarios.

Furthermore, if multiple energy and environmental impacts are explicitly included as bundled incentives and price premiums, the IRR increases for both business cases to between 33% and 43%, depending on energy price outlook. The impacts considered in the Princeton report include fossil energy savings, renewable energy markets, emission reductions, energy security and diversity, economic development, and reaping the benefits of government R&D.

It must be expected that capitol costs in 2008 are considerably higher than in 2005, both for theTomlinson boiler and gasification systems. When combined with much higher energy costs, one might assume that the IRR would still be positive, but IRRs have not been updated with new cost assumptions.

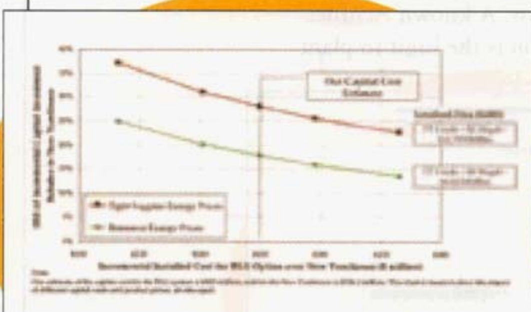


Figure 2. Allowable incremental capital cost for FTL biorefinery relative to new Tomlinson investment for different target IRR values under the two energy price scenarios.

The accuracy of captal cost estimates was within ±30%, so the Princeton report included analysis of sensitivity to capital cost assumptions. The two figures on this page from the report show sensitivity of IRR under the two price scenarios to variations in capital costs, with approximately ±30% variation in capital costs of black liquor and biomass to liquid gasification (BLG) systems. **Figure 1** is for the configuration producing DME as an LPG blendstock substitute and **Figure 2** is for the configuration productnig FT crude.

Levelized prices for biofuel products over 25 years (in constant 2005 dollars at the plant gate without incentives) were projected to be only US$0.66/gal for DME sold as an LPG substitute and US$0.96/gas for FT crude as a pretroleum substitute in the Reference scenario (or US$0.99/gallon for DME and US$1.54 for FT crude in the High Price scenario).

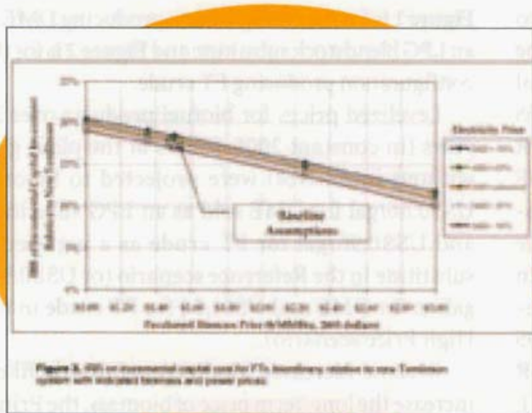
Because increased local demand would likely increase the long-term price of biomass, the Princeton study also analyzed IRR sensitivity to purchased biomass costs. As shown in **Figure 3,** the baseline assumption for levelized price of purchased biomass input was $1.53 per million Btu, equivalent to a wood biomass price of $27.40 per dry ton (at 17.9 million Btu per dry ton of wood biomass).

The IRR calculations above were based on 50% equity financing (50% borrowed capital at 8% interest). Higher rates of return on equity will be obtained if more capital is borrowed at the lower interest rate (and vice versa if less is borrowed). There may also be potential for higher value chemical products or byproducts, but the Princeton report focused on transportation fuels with large markets, such that the biorefineries would have litte or no price impacts on the market.

INTEGRATED VS. STAND-ALONE BIOREFINERIES

Biofuel yields per ton of biomass are higher for all pulp mill biorefineries modeled in the Princeton study than for "stand-alone" biofuel plants, while capital costs per unit of biofuel are similar. Thus, the integrated pulp mill biorefinery is a more efficient means of converting biomass to biofuels.

This efficiency stems from the fact that thermochemical biorefineries have considerable waste heat available and pulp and paper facilities are well-matched heat sinks. In orther words, the fact that a forest biorefinery does not have the economies of scale compared with one based on follis fuels is offset by the value of integration with the mill. That is, some of the capital and operating costs are incurred to provide the mill with steam, power and reconstituted pulping



than for "stand-alone" biorefineries (above the dashed line). the higher yield values for the integrated pulp mill biorefineries arise primarily because a portion of the total biomass input is charged to services and co-products proviced in additional to liquid fuel production.

In the integrated pulp and paper mill biorefinery designs, a portion of the input biomass is used to meet the pulp and paper mill's process steam, power and chemical recovery needs, which are currently met by the Tomlinson and bark boilers. In a few of the cases studied in the Princeton report,

liquors, which have significant ecomonmic value. As a result, the net cost associated with liquid fuels production is lower than for a stand-alone biorefinery.

A key measure of biorefinery efficiency is the liquid fuel yield per ton of dry biomass input to the facility. Figure 4 (from the Princeton study) shows liquid yields calculated on the basis of both ethanol and gasoline for a variety of biorefinery designs. Included in this figure are results from several studies:

É Two stand-alone biorefinery designs developed by the National Renewable Energy Laboratory (NREL) for corn-stover conversion to ethanol via enzymatic hydrolysis routes—one based on vintage-2000 technology and the other based on advanced technology

É Three results published by NREL for stand-alone thermochemical conversion via gasification and mixed alcohol synthesis

É Three results for stand-alone thermochemical conversion of switchgrass via gasification and synthesis to DME (two plant designs) and to Fischer-Topsch liquid fuels, developed in the Renewable Biomass for America's Energy Future (RBAEF) project.

The remaining 10 results correspond to biorefineries integrated with pulp mills, including:

É Three results from a 2005 European Union study based on black liquor gasification and DME or Fischer-Topsch liquid fuel synthesis

É Seven designs based on separate black liquor gasification with and without solid biomass gasification.

The key result from Figure 4 is that liquid fuel yields are higher or substantially higher for all pulp mill biorefineries (below the dashed line)

a significant amount of power (in excess of that provided by the Tomlinson boiler base case) is generated in efficient combined cycles. They are:

É MA (mixed alcohols with a 6FA gas turbine, generating capacity around 82 MW up to 89 MW)

É FTa (Fischer-Tropsch with a 6FA gas turbine)

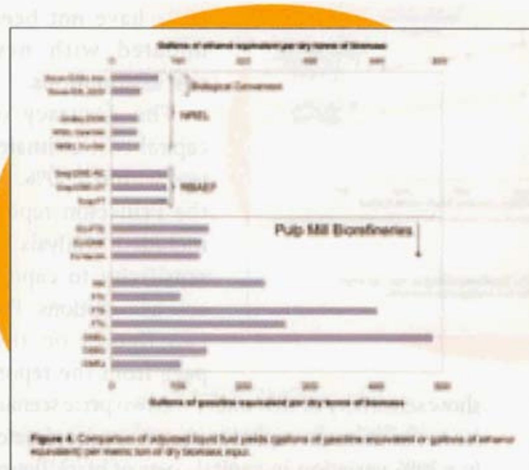
É FTb (Fischer-Tropsch with a larger 7FA gas turbine, generating capacity of 182 MW)

É DMEb (Dimethyl Ether with a 6FA gas turbine)

É DMEc (Dimethyl Ether with a larger 7FA gas turbine).

In these cases, the liquid fuel yields are exceptionally high due to allocation of a portion of the input biomass to power generation.

Of course efficiency is only part of the economic picture, especially if high efficiency is gained at high capital cost. A known Achilles' heel of biofuels production is the limit to plant



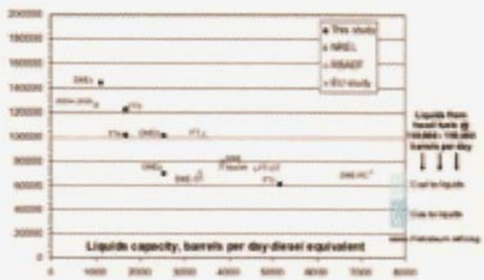


Figure 5. Effective capital investment intensity (2005 dollars/barrel of diesel equivalent/day) for liquid fuels production as a function of liquids production capacity

size scale imposed by transportation distances for low energy density biomass. As a result, biofuels plants inevitably have higher capital intensity than those that use fossil sources.

Another interesting integration benefit is the impact on specific capital cost, i.e. the capital investment required for a unit production of liquid fuels. As shown in **Figure 5** (from the Princeton report), the specific capital intensity of biofuels production can approach that of coal-to-liquids facilities. The most striking point demonstrated in Figure 5 is that similar capital intensities are achieved for some of the integrated biorefinery designs at a scale 20 to 50 times smaller than coal-to-liquid facilities.

CONCLUSION

The Princeton study has shown that the production of liquid fuels and chemicals via gasification of black liquor and woody residues in an integrated forest biorefinery can provide very attractive IRRs for kraft pulp and paper mills, replacing their Tomlinson boilers. A key result is that liquid fuel yields are substantially higher for all pulp mill biorefineries than for “stand-alone” biorefineries.

While the mill continues its production of traditional products, e.g., pulp and paper, the add-on biorefinery provides chemical recovery services and co-produces process steam for the mill, some electricity, and an entirely new line of products in the form of liquid fuels. While compared with replacing a recovery boiler in kind, a biorefinery requires larger capital investments; it also provides higher energy efficiencies, lower air emissions, and a more diverse line of products.

The study shows that the IRRs can rise in the 33%-43% range if positive incremental energy and environmental benefits associated with biofuel production are rewarded by incentives such as tax credits comparable to those existing today for ethanol. The study also points out that higher IRRs are possible at higher crude oil prices, a situation existing today.

In addition to significant economic benefit, widely implemented biorefineries in the U.S. would serve the national interest by providing a native source of fuels that replace imported oil, create new jobs, and result in significant environmental benefits for the nation. As the price of oil continues to escalate, the production of native biofuels will become more economically attractive to a financially stressed industry and more needed by the nation, whether produced in stand-alone bioconversion facilities or in biorefineries integrated with pulp mills.

The AF&PA Agenda 2020 CTO Committee Working Group that produced this report includes Tom Belin, Potlatch; Craig Brown, Weyerhaeuser; Eric Connor, TRI; Jim Frederick, IPST; Peter Ince, FPL; Ryan Katofsky, Navigant Consulting; and Gerard Closset as coordinator. For more information about Agenda 2020, visit www.agenda2020.org.

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