Thermochemical Versus Biochemical

Dynamotive Energy Systems Corp. has been turning biomass into bio-oil for several years for use in power generation and other low-grade fuel applications. Bio-oil, a densified form of biomass, also has significant potential as a feedstock for cellulosic ethanol production. As an alternative to the enzymatic or biochemical approach to making cellulosic ethanol, this pyrolysis model could solve some of the logistical and processing obstacles associated with commercializing non-grain ethanol.

By Nicholas Zeman

Dynamotive's bio-oil and intermediate bio-oil products are price-competitive replacements for No. 2 and No. 6 heating oils, which are widely used in industrial boilers and furnaces.

While the technology to produce cellulosic ethanol on a large scale is being perfected, researchers are still grappling with the particulars involved in the collection, transportation and storage of millions of tons of biomass. Canadian-based Dynamotive Energy Systems Corp. has developed a business model that capitalizes on the decentralization of biomass. "This is a distributed approach to biomass," says Andrew Kingston, CEO of Dynamotive, which is headquartered in Vancouver, British Columbia. The company also has a different approach to the production of energy and ethanol from biomass.

Although burning biomass alone produces energy, Dynamotive's platform focuses on the principle that converting biomass to bio-oil multiplies the energy yield 12 to 15 times. The company's bio-oil and intermediate bio-oil products are price-competitive replacements for No. 2 and No. 6 heating oils, which are widely used in industrial boilers and furnaces. Even more importantly, bio-oil is priced at $25 to $35 a barrel, nearly half of the current price for crude oil. Furthermore, it's a form of biomass that's easier to transport and has considerable advantages in terms of storage, Kingston says.

Dynamotive Energy Systems Corp. is headquartered in Vancouver, British Columbia, and has a plant in West Lorne, Ontario, and one under construction in Guelph, Ontario.

Kingston

Radlein

Dynamotive's foundation plant in West Lorne, Ontario, is collocated next to the Erie Flooring and Wood Products factory and uses the waste sawdust to make bio-oil. The plant is currently being expanded, which will allow it to increase the amount of sawdust it uses from 100 metric tons per day to 130 metric tons. At press time, the upgraded reactor and burner systems were ready for shipment and the plant was expected to be operational by the end of the summer. Dynamotive is also constructing a plant in Guelph, Ontario, that's designed to process 200 tons of cellulosic biomass per day and produce 12.2 MMgy of bio-oil, with the equivalent energy content of 550 barrels of conventional oil.

Bio-Oil to Ethanol

Bio-oil can be further refined in various ways, according to Desmond Radlein, lead scientist for Dynamotive. With the known technologies to convert biomass to synthetic gases—specifically Fischer-Tropsch—bio-oil can be made into ethanol. That could solve some of the problems involved in efficiently transporting biomass to ethanol plants. In order to be competitive, plants that could convert biomass to ethanol need to be able to process 3,000 to 5,000 tons of biomass per day. Plants of this nature are being built in Holland and Germany, and there is a potential market for biomass in Europe, but the raw materials couldn't be exported from U.S. shores, Radlein says. By converting the biomass into bio-oil, transportation opportunities are created. "You can ship bio-oil in a tanker," he says. "You can't do that with biomass."

If that is the case, then pyrolysis might have been overlooked as a feasible process for cellulosic ethanol production. Some studies have shown that producing ethanol from corn can only provide a small fraction of U.S. fuel needs, Radlein says. However, those same studies report that if all the country's biomass was utilized, then renewable fuels could supply a very large fraction of the transportation fuels demand. One way to do this is with bio-oil, Kingston says.

Kingston and others believe that it might be more feasible for a would-be cellulosic ethanol, producer to contract with Dynamotive for bio-oil and use it to make ethanol instead of attempting to harvest and collect woody biomass on its own. "For the conversion of woody materials, I certainly think bio-oil has a lot of potential," says Bruce Dale, a professor of chemical engineering at Michigan State University. According to Kingston, it's just simpler to process bio-oil into cellulosic ethanol than it is to deal with raw biomass. Producers wouldn't have to harvest and transport raw materials like agricultural residues or cultivate dedicated energy crops.

Through pyrolysis, bio-oil can also be made from corn stover, which is left behind in a field after the corn is harvested. "There's a synergy there," Radlein says. "You can utilize the waste stream, reduce the cost and become more environmentally friendly." Not only could bio-oil be a feedstock for cellulosic ethanol producers, but it could also complement the use of natural gas as a power source for ethanol plants. Conversely, one central bio-oil plant could supply several energy users in distributed locations, or several plants could supply numerous end-users, just as in the petroleum industry. If it's easier to transport bio-oil instead of biomass, a pyrolysis plant could locate near the biomass source and ship bio-oil to the ethanol plant. That could eliminate some of the logistical problems that have dogged the development of the cellulosic ethanol industry. "We want to develop partnerships and find areas where we can collocate these plants," Kingston says. A bio-oil system also requires 95 percent less land area to store the same amount of energy in the form of biomass.

George Huber, a professor of chemi-

cal engineering at the University of Massachusetts-Amherst, agrees with Radlein that economy-of-scale analyses indicate that a cellulosic ethanol refinery has to be very large to be viable, and needs to have a close and dependable source of biomass. "Really, outside of a 50-mile radius, it begins to become very expensive to transport biomass," Huber says. The pyrolitic method, in which ethanol is made from bio-oil instead of biomass, is a way to solve this problem, Huber says.

Dynamotive's efforts in Darwin should be of interest to many other cities that wish to avoid disposing of large amounts of green waste that create methane gas, a harmful greenhouse gas.

Perfecting a heat-integration system is also important for the development of cellulosic biorefineries. "The idea is that you power the processes that require heat from other processes in the plant that generate heat," Huber says. Because distillation is the most energy-intensive, expensive aspect of ethanol production, producers are constantly looking for ways to minimize its cost.

Fast pyrolysis also stands as an alternative to the enzymatic or biochemical approach to the biomass-to-ethanol conversion. So the big question is: What's the advantage of pyrolysis over the enzymatic approach in the production of cellulosic ethanol? "There's been 30 years of work done on enzymatic pretreatment technologies," says Robert Brown, professor of thermal engineering at Iowa State University in Ames. "At the same time, there has been very little done with pyrolysis in terms of truly optimizing the process, so in my opinion that is a significant economic advantage over some of the other approaches to making cellulosic ethanol. There are all kinds of possibilities, and virtually none of them have been explored."

Politically, the support for cellulosic ethanol has been focused on biochemical conversion processes, says a source at a U.S. laboratory who asked to remain anonymous. Enzyme companies have lobbied for federal funding to be funneled toward biochemical research efforts, while thermochemical approaches appear to have been overlooked. Focusing on enzyme development may have been logical but perhaps mistaken, says the source, adding that it wasn't until recently that pyrolysis began to receive attention and support in the cellulosic ethanol realm. "There's been a lot invested in enzymatic technologies," Brown says. Those investors have a lot to lose if an alternative technology draws the attention of producers.

"In my opinion, I don't think companies focusing on cellulosic ethanol are trying to stop bio-oils from being commercially viable," Huber says. "I think the bio-oil industry is behind in promoting itself, and I think this will change in the future. The real competitor is petroleum-derived feedstocks versus biomass-derived feedstocks, not bio-oils versus ethanol. In fact, I think a case could be made that if you can make one type of fuel from cellulosic biomass you can make another type of fuel as well." Huber believes it's important that economics—not governmental policies—should decide which are the best processes for making biofuels.

Dynamotive executives believe it's easier and more efficient to transport bio-oil to an ethanol facility, than it would be to move the raw biomass.

Across Continents

Dynamotive's pyrolysis can be used to turn a variety of materials into bio-oil including sugarcane bagasse. The burning of sugarcane fields in Latin America after harvesting is a practice that's being phased out, Kingston says. This could make an abundant source of biomass available. There are many opportunities around the world for refining biomass, like those that exist for Dynamotive in South America, but opportunity doesn't always alleviate risk. "There's a lot of interest and a lot of plans in the works, but we need to see how the facility at Guelph performs before we put further millions at risk," Kingston says.

Miscanthus has also been identified as a feedstock. Dynamotive and Consensus Business Group, also headquartered in Vancouver, started a biomass joint venture last year. Consensus Business Group will secure long-term project opportunities for Dynamotive to produce bio-oil. Also, Dynamotive and Rika Biofuels, a European biodiesel company, studied the feasibility of producing bioenergy crops in the Ukraine. The companies are planting enough miscanthus at a 5,000-acre energy park to replace the energy produced by 250,000 barrels of crude oil.

Dynamotive is also involved in a project in Australia to turn the city of Darwin's green waste into a biofuel for electric generation. Excess green energy generated in parallel with the pyrolysis plant would be fed into the Darwin electric grid. Bio-oil produces substantially less nitrogen oxide emissions than conventional oil, as well as little or no sulfur oxide gases, a cause of acid rain, the company says. Dynamotive's efforts in Darwin should be of interest to many other cities that wish to avoid disposing of large amounts of green waste that create methane gas, a harmful greenhouse gas. It's especially important in countries like China, which has a high level of coal smoke. "China will have to implement a variety of solutions [to meet the requirements of the Kyoto Protocol]," Kingston says. "Dynamotive is part of that mix."

Kingston, a former oil company executive, believes biobased fuel is a way to promote waste reduction and meet clean air standards like those outlined in the Kyoto Protocol, which is being implemented internationally. **BIO**

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