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"Follow-the Crop" Biofuel Production System

The Problem

The production of biofuels in the US is at a substantial roadblock. Simply stated, the economies of scale that allow the US petroleum industry to minimize both production and transportation costs are currently not available to the biofuel industry.

The Transportation Conundrum

The primary reason is the high cost of transporting large quantities of low density, low value biomass to biorefineries. Because of these costs, the current biofuel production system is incapable of economically sustaining the 2-5 billion gallons/year biorefineries that will be needed to cost-efficiently supply US transportation fuel demand. (The average US petroleum refinery capacity is 1.7 billion gallons/year (146 refineries) and the ten largest refineries that supply 23% of all capacity average 5.5 billion gallons/year. US DOE/EIA 2008 data.)

Current R&D Does Not Address The Issue

The current focus of US biorefinery R&D is not directed at overcoming this roadblock. Instead, the efforts of industry and current DOE/USDA biorefinery demonstration programs are aimed at creating integrated biorefinery systems based on one crop or crops from within a constrained geographic area. Furthermore, the design of these biorefineries combine biomass pretreatment, sacacharification, and fermentation into one system.

The Atlantic Biomass Solution

We propose to transform the current single crop integrated biorefinery paradigm to overcome this roadblock. This new approach to biofuel production will incorporate two interrelated concepts.

One, the pretreatment and sacacharification of field biomass is taken out of the centralized biorefinery and distributed to a number of low-capital enzyme based subsystems located in growing areas. These decentralized facilities would convert the low-density, low value biomass into high density, medium value biofuel intermediates using a commercial version of the biomass processing system currently being patented by Atlantic Biomass.

Biofuel intermediates would be shipped via tank truck, or even lower cost trains, to large scale biorefineries for chemical or thermochemical conversion to finished biofuels. These large-scale facilities would range from dedicated cellulosic ethanol plants to existing multi-product petroleum refineries retrofitted to utilize biomass intermediates. The location of these biorefineries would therefore not be limited to the immediate radius determined by the cost of crop biomass transport. Instead their location could be based on optimized transportation and market distribution criteria. It is envisioned that in most cases they would be co-located with existing petroleum refineries in order to make use of the existing transportation, distribution, and industrial infrastructure.

Two, in all future biofuel scenarios that maximize sustainable biomass yield for biofuel production, different, environmentally suitable, crops will be grown in a variety of agronomic conditions. This will include planting energy crops such as non-sucrose “energy” sorghum, currently producing up to12 tons/acre of dry biomass in DOE/USDA test plots, in rotation with food or animal feed crops and planting perennial grasses in non-contiguous stands. Many of these perennial grasses, such as switchgrass which has a current yield of 5-6 tons/acre, will be in stands smaller than those required to fuel 2nd generation cellulosic ethanol plants. Furthermore, many of these stands will be conservation areas which will limit their availability for harvesting. While these agronomic practices ensure crop sustainability, they do not favor the economical processing of the biomass into biofuels under the current integrated biorefinery paradigm which requires both short biomass transport distances and the same input crop each year since the biorefinery design was optimized for that crop.

Therefore, instead of bringing sufficient supplies of biomass to processing facilities, we will take the decentralized enzymatic conversion units to the crops. Following the model of wheat harvesting combines that follow the harvest season, we will develop a “Follow-the-Crop” biofuel intermediate production system.

The Follow-the-Crop module is based on the portable ethanol production system that Encore Biofuels, LLC is currently engineering. Retrofitted shipping containers complete with internal environmental controls will be the basis for the modules. This will allow for inexpensive initial and transport costs. It is similar in design to the Deployable Aqueous Aerobic Bioreactor, or DAAB, was developed by the Texas Research Institute for Environmental Studies at Sam Houston State University, and PCDworks.

The complete system will consist of: a) the modular units of the enzyme based biofuel intermediate production process, and b) a control/deployment system for the scheduling, monitoring, and control of the individual units. A combination of GPS locators on the modules and a database of contracted growers, including GIS location software, will be used to maximize deployed/processing time while minimizing transportation costs. Individual modules will include software and hardware connections so they can be operated in single or multiple mode to process crops on fields as small as 10 aces or as large as 1,000.

Positive Transformation of the US Biofuel Industry

The Energy Independence and Security Act (EISA) of 2007 established a Renewable Fuel Standard (RFS) that called for the production of 21 billion gallons/year of cellulosic based and additional advanced biofuels by 2022. To help meet this Congressional mandated goal, the Dept. of Energy has funded eight cellulosic ethanol plants and currently has a solicitation out to fund a number of additional advanced biofuel pilot and demonstration scale biorefineries. However, in all cases, these DOE programs are designed to fund biorefineries using existing technologies.

Testimony from representatives of the cellulosic biofuel industry at a recent House Agriculture Committee hearing (21 May 2009) stated that no cellulosic ethanol is currently for sale and the industry would not be able to meet the cellulosic ethanol RFS goal for 2010 or 2011 and meeting out-year goals with current technology looked problematic.

Reasons for this deficiency were presented at the 19 March 2009 DOE biorefinery annual peer review sessions. The two largest problems discussed by the companies that were awarded DOE cellulosic ethanol grants were: 1) lack of available biomass, and 2) lack of performance from the combined sacacharification/biochemical (fermentation) systems.

The biomass availability issue comes down to the biofuel transportation conundrum.

> **How can you transport enough low-density, low-value biomass to fuel a cost-effective integrated biorefinery that has all the biofuel production functions: pretreatment, sacacharification, and biochemical transformation at one site and still make money?**

Simply put, you cannot, if you follow that paradigm.

That is why the “Follow-the-Crop” biofuel intermediate production system is transformational. By splitting the integrated biorefinery paradigm and rethinking the entire concept of biofuel production the transportation conundrum can be overcome.

The Follow-the-Crop system decentralizes the first stage of biofuel production, the conversion of plant biomass into high density, medium value intermediates such as soluble C-5 and C-6 sugars, while allowing the second stage, biochemical conversion to become highly centralized and highly efficient. Nationwide deployment of the Follow-the-Crop system would provide new, year-round employment in technical and equipment maintenance jobs needed to staff the biofuel intermediate production modules and to operate and maintain the new or expanded biorefineries needed to meet advanced biofuel production demand.

Going even further though, the Follow-the-Crop system makes the biofuel intermediate production system portable. This not only allows multiple crops and agricultural residues to be used as biofuel feedstocks, but, more important, will allow farmers to utilize their marginal lands and expand their selection of crops without the necessity of planting hundreds of contiguous acres. This would allow significant quantities of total energy biomass to be grown outside the Midwestern “grain-belt.”

By creating a viable market for environmentally suitable “energy” grasses and agricultural residues grown in stands as small as 10 acres, the deployment of this system would improve the income of small and medium growers. This positive impact would greatly help rural economies in the southeast and northeast.

Adding this acreage, would enable the United States to not only grow enough biomass to meet the 2022 goals of the Renewable Fuel Standard (21 billion gallons/year), but will also set the country on the path to significantly reduce the importation of petroleum. At: 1) an average of 10 tons of biomass/acre, 2) a 55% conversion efficiency, and 3) the proposed CAFE fuel economy standards taking effect, 39 million acres could produce the 60 billion gallons of fuels needed to power the light duty vehicle fleet of the country.

From a macroeconomic perspective, the Follow-the-Crop system will transform the American 2nd and 3rd generation advanced biofuels industry into one coherent system rather than remaining a collection of uncoordinated, geographically constrained small industrial facilities. By changing the feedstock of biofuel refineries from individual specialized crops into common commodities, the entire biofuel industry can then respond to supply and demand market forces. The results of this transformation would include:

1. Standardization of biofuel chemical conversion facilities results in lower production costs.

2. Year-round availability of a common feedstock increases the number of days of biorefinery operation. This greatly improves the economics of biofuel production and makes the industry a better investment.

3. With biofuel feedstocks becoming non-crop specific, “energy” crops can be selected on the basis of specific environmental and agronomic factors rather than suitability for the local ethanol plant.

4. A reliable and sustainable feedstock will encourage investment in 2nd and 3rd generation biofuels such as drop-in replacements for gasoline, diesel, and jet fuels. The following diagram shows some of the potential uses for soluble C-5 and C-6 soluble sugars.

We propose to overcome this roadblock with a transforming approach called the “Follow-the-Crop” biofuel intermediate production system.

Instead of bringing biomass to biorefineries, the bioconversion technology will go to the crops. Following the model of combines that follow the harvest season, “Follow-the-Crop” modules will be deployed nationwide as energy grasses and crops are harvested. These modules will convert the biomass into high density biofuel intermediates using a fast, low-cost enzyme system. The biofuel intermediates would be then be shipped via truck or train to large scale biorefineries for conversion to marketable biofuels.