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Biobased Commodity Feedstocks

PERP 09/10S4

Report Abstract
February 2011

Nexant

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INTRODUCTION

Throughout most of human history, crops, other plants, and animals have provided for most human economic needs. Field crops, such as starch crops (grains and tubers), oilseeds, and sugarcane have been produced for many centuries, along with fruits, vegetables, and honey, as sources of quick and storable food energy. Fermentation alcohol has been made from all the starch and sugar resources listed above for millennia. Wood, straw, dung, charcoal, and grasses have also been used as solid cooking and heating fuels historically, and continue to be used in the developing world. Wood, raffia, cotton, and linen have provided the materials for clothing, furniture, and other durable goods. Soap has long been made from virgin and waste fats and oils.

With concerns over the implications of the high volumes and ubiquitous use of fossil fuels, society is now considering returning to the farm, forest, and ocean to source fuels and materials going forward.

Bio-feedstock drivers

Broad concerns about the future of the global economy and the natural environment have brought about a new goal for industries, consumers, and governments to strive towards in the twenty-first century: sustainability. For years, environmental and conservation groups have been the primary proponents for decreasing consumption of non-renewable resources and reducing pollutant emissions. Now, many academic and political voices have entered the discussion, recognizing the fundamental economic gaps presented by “externalities” like greenhouse gas emissions and finite supplies of fossil fuels.

The energy and chemicals industries are among those most heavily scrutinized for sustainability. Recent high volatility in energy and other commodities prices proved that these industries have much at risk when new scarcities emerge. Major concerns exist both upstream (crude oil supply) and downstream (greenhouse gas emissions) of the hydrocarbon-based energy and chemicals industries. While many economists project more stable energy markets in the short term, discussion of greenhouse gas impact on climate is reaching a peak. Many Western businesses are bracing themselves for the potential implementation of a carbon tax or cap-and-trade system. Meanwhile, concerns over peak oil long-term and a repeat of the 2007-2008 fly-up in global commodity prices loom as the global economy recovers from the 2008-2009 recession.

Biofuels and bio-based chemicals have been widely touted as a potential solution for dependence on petroleum. They also have a favorable GHG (greenhouse gas) balance compared to fossil fuels and petrochemicals, because any carbon sourced from biomass can be directly traced to atmospheric carbon dioxide (CO_2) via photosynthesis. However, some analyses are leading to harsh criticism of the rapidly developed biofuels industry and related emerging bio-based chemicals ventures. Many critics are concerned over competition between crops for food and the use of the same crops and farmland for fuels. Other key questions lie in the nature of overall energy balances for biofuels, whether significant amounts of fossil fuel consumption can be displaced, and when either biofuels or bio-based chemicals will achieve cost parity and thus economic sustainability.

Against a difficult backdrop, it is clear that bio-based industries are at a crossroads. Because of the increased emphasis on lifecycle analysis for social, economic, and ecological factors, the industry players are becoming increasingly familiar with the details of bio-feedstocks. As an industry expert, Nexant has developed extensive knowledge in this area. A broad survey of the drivers, politics, and various external influences on the sector is presented in this section to establish the perspective for this report.

The following important topics are discussed in the introductory section to this report:

- Issues and selection criteria (Co-products, Process Feed Flexibility, Supply Model, etc.)
- Value Chain Players

FOOD-BASED COMMODITIES TECHNOLOGY AND SUPPLY/DEMAND

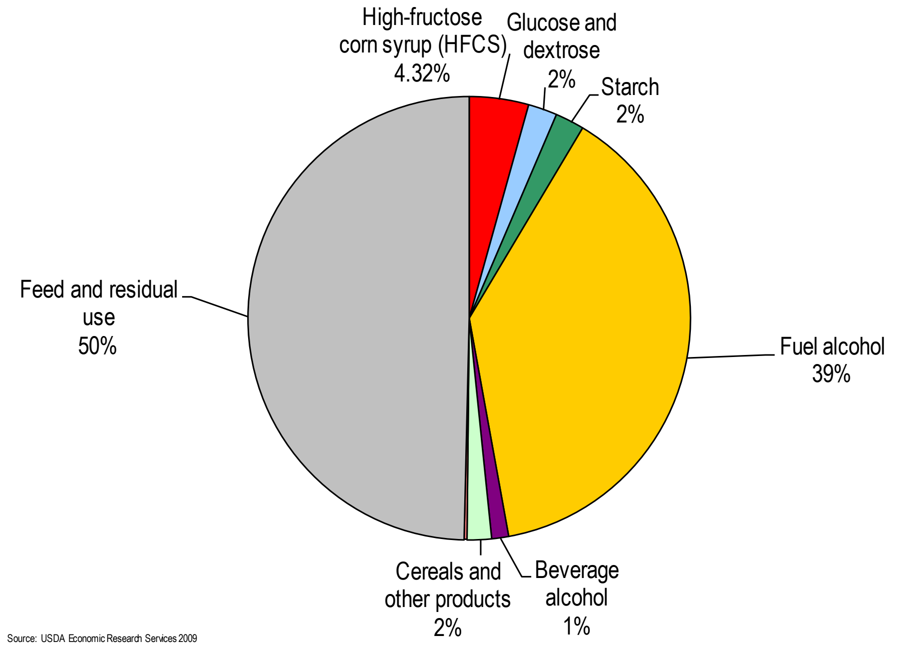
Technologies and supply/demand for food-based primary commodities are discussed.

One of the most well-known food-based commodities is corn. Corn (as it is known in the United States and Canada, or "maize", as it known elsewhere) is a hardy and versatile crop, capable of growing in many subclimates globally between the latitudes of 50° North and 50° South. It can grow at altitudes ranging from sea level up to 3 000 meters and can take advantage of long growing seasons and higher temperatures to add substantial amounts of biomass. It does best in climates with wet spring and hot summer seasons, such as in the mid-Western region of the United States. The usefulness of corn as a feedstock for ethanol continues to be a major driving force in the development of a biofuels industry in the United States, but along with ethanol's rise to prominence has come much controversy. Corn is the United States' largest crop output and is supported by a long and established history of government subsidies pressed by farmers' lobbies. The reasons for corn dominating the United States ethanol market include high carbohydrate yield per acre and relative ease of saccharification (conversion of starch to sugar) allowing good overall conversions to ethanol by present-day fermentation procedures. However, corn is a high-input crop. Traditionally there has been little effort to limit fossil fuel and fertilizer use for growing corn. Thus, its currently-established agricultural practices produce high crop yields, but the end result is a disappointing greenhouse gas balance and significant fossil fuel inputs. Since greenhouse gas reduction and reduction of petroleum imports are drivers for investing in biofuels, many experts believe that corn ethanol will be a lightning rod for opposition to biofuels until significant changes are made in the way the crop is grown.

The Figure below illustrates the most recent statistics for corn consumption in the United States.

Figure 0.1 U.S. End Consumption of Corn, 2009

(Later quarters projected - Source: FAO (2010))



The technologies and supply/demand for the following food-based commodities are discussed in this section of the report:

- Corn, Sugarcane, Soybeans, Oil Palm, Rapeseed, Wheat, Sunflower, Sweet Potato, Milo (Grain Sorghum)

NON-FOOD BASED COMMODITIES TECHNOLOGY AND SUPPLY/DEMAND

Technologies and supply/demand for non-food based commodities are discussed. Energy grasses are an example of a non-food based commodity. The biggest advantages for switchgrass are its versatility and hardiness. It can thrive in a wide distribution of geographies and in soils of low quality. After becoming established in a year or less, switchgrass stands may continue to thrive for as long as ten years with annual or more frequent harvesting. This is an eminent trait among biofuels feedstocks. It can thrive on marginal farmland, or even completely non-arable land, such as sandy or gravely soils in humid regions, or on soil too prone to erosion to support corn. Like other plants of its type (i.e., "C_4-photosynthetic" plants, which includes grasses and grains), switchgrass is both resource-efficient and low-input.

Much of the discussion and interest in switchgrass is relevant to miscanthus. Miscanthus is a genus containing 15 species, and is native to subtropical and tropical areas in Africa and southern Asia. The main difference between the two grasses is that that switchgrass may be planted with seeds, while miscanthus must be planted with rhizomes (tuberous roots). As a result, initial costs for planting miscanthus are higher, but planting costs are of less importance for perennial plants and miscanthus compensates for these with a high annual yield. For the most part, switchgrass is envisaged to succeed the United States, whereas miscanthus is being championed in Europe.

Agricultural Model and Lifecycle Analysis for energy grasses as a biomass feedstock for biofuel production is presented.

The following non-food based commodities are discussed in this section of the report:

- Energy Grasses (Switchgrass/Miscanthus, Energy Cane), Sweet Sorghum, Wood Chips (Poplar, Willow), Non-food Oil Flowers (Camelina), Other Oil Flowers (Jatropha), Algae (Cultivation Research, Ethanol Production), Tung Oil, Black Soldier Fly.

DERIVATIVE FEEDSTOCKS

Vegetable oils are an example of what is meant by a derivative feedstock. Vegetable oils are refined for food applications by removing many types of impurities that affect taste, odor, acidity, oxidation (rancidity) resistance, clarity, color, gumminess, etc., which might not sufficiently affect performance as a biodiesel feedstock to warrant the cost of refining. Refining steps can include degumming, refining/neutralization, bleaching, deodorization, and fractionation (including winterization) either by cryogenic or solvent-based partial crystallization. Major markets and pricing, processing model and lifecycle factors are discussed.

Another example is waste cellulosics, including municipal solid waste (MSW), putrescible fractions, pulp and paper industry wastes, and forest product wastes. The cellulosic components of MSW can sometimes be separated from processed components either by the consumer or by waste processing entities. In this form, MSW becomes an attractive biofeedstock because the waste has an either zero or negative feedstock cost. Forms of municipal solid waste that would be appropriate for cellulosic biofuel conversion include wood waste, cardboard, grass waste, mixed paper, and alternative daily cover (ADC). ADC is another name for topcoat, or any non-earthen material used to seal the active part of a landfill from the atmosphere or weather. Broadly, ADC materials are ash, sludge, shredded tires, construction wastes, foam products, compost and cement – obviously not all of these are cellulosic, but the ADC materials that are cellulosic can be used.

The derivative feedstocks discussed in this report include:

- Sugar Products (Molasses, Glucose, High Fructose Corn Syrup), Starch, Cassava Chips, Vegetable and Algae Oils, Animal Fats and Waste (Fish Oils, Yellow And Brown Greases), , Waste Biomass (Bagasse, Corn Stover, Straw, Palm Empty Fruit Bunches, Algae Biomass), Glycerol, Soy Mean, Corn Gluten Meal, Dried Distillers Grains with Solubles, Waste Cellulosics,

APPLICATIONS

Much research effort and investment has been recently applied to bio-based fuels and chemicals, such that many applications are now well-proven for the various biofeedstocks discussed in previous sections. Nexant has selected some of the most important and common pathways for conversion of these feeds to provide examples of the downstream options. Applications can be segmented a number of ways, but the following view of feedstocks and pathways seems most intuitive:

- Feedstocks producing oils (lipids, which can be waste or virgin, vegetable or animal) are typically processed to produce substitutes or blendstocks for diesel fuel. Nexant describes the transesterification process predominantly used to produce most biodiesel globally, as well as new routes to renewable diesel substitutes.
- Carbohydrate feedstocks currently have dominant market share in the fermentation pathway, especially to make bioethanol, but also increasingly to make "green" chemicals. This includes plants with a high proportion of hydrolysable starch or fermentable sugar (like corn or sugarcane) as well as hydrolysable cellulosic feedstocks (such as wood chips or palm EFB).
- Thermochemical pathways are also described in this section. These are more flexible in terms of feedstock feasibility through different levels of heating, among technologies, used to break down the natural carbohydrates, lignin, and other components into various fractions of gases, liquids, and char before they are reacted to form fuels or chemical products. Generally, high-yield cellulosic crops will be preferred, but waste materials also have good prospects in the thermochemical space.

ECONOMICS

Nexant compiled cost of production models for many of the leading biofeedstocks globally mentioned in other parts of this report. These models focus on the following data points:

- Real estate/farmland cost, which is approached differently for various feedstocks. This is further elaborated in the report
- N-P-K fertilizer (and in some cases micronutrients as well) utilization and distribution in the field, and the associated labor cost. Most other nutrients are provided in the soil, the cost of fertilizer is one of the most important raw material inputs in these agricultural models
- Agricultural chemicals and crop protection chemicals, which are various types of insecticides, herbicides, and other pesticides designed to protect the crop from insects, weeds, fungi and other threats to the harvest are modeled, but also lime and some crop-specific chemicals
- Costs of various activities such as planting, weeding, harvesting, transportation, machinery operation and product transport.
- Catalyst, chemicals and utilities for derivative feedstocks that are processed in a plant
- Capital recovery budget for maintenance or upkeep of farm equipment and payback of interest on capital employed before receiving revenues from the harvest
- Taxes and insurance (on crops, equipment, etc.), where necessary

Each feedstock studied has individual inputs and characteristics, and as such the models vary considerably. Several of the feedstocks mentioned in this report are derivatives, meaning that they are not farm-gate crops themselves, but a result of processing a commodity feedstock – for example, crude degummed soybean oil as contrasted with soybeans.

Specifically, Nexant uses the following categories to frame the biofeedstocks modeled in this report:

Farm-gate crops:

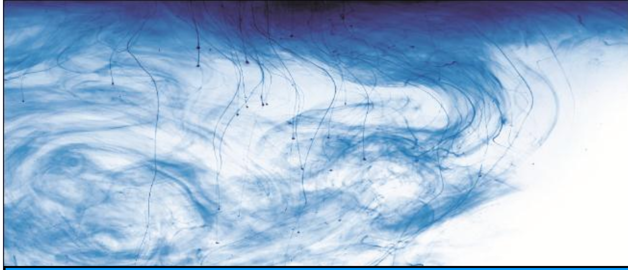
- Corn grown in the United States; one model in a field that grows corn continuously and another that uses a rotation with soybeans
- Sugarcane grown in Brazil; one model assumes the cane is harvested using cutting machinery and another that assumes a harvest via manual cane-cutting
- Soybeans grown in the United States; one model in a field that grows soybeans continuously and another that has a year-on-year rotation with corn
- Palm fresh fruit bunches (FFBs) grown in Malaysia
- Cassava grown in Thailand – manual harvesting only

Packed, transported biomass energy crops:

- Switchgrass grown in the United States
- Hybrid poplar logs grown on a plantation in the United States; one model in which the plantation is located where there was no existing forest, and another model assuming sustainable harvesting and replanting of an existing forest

Derivative feedstocks (natural oils):

- Crude, degummed soybean oil from soybeans crushed in the United States
- Crude palm oil from palm oil seed crushed in Malaysia
- Algae oil; one model from algae grown in an (industrially made and installed) open pond, and another model from algae grown in a photobioreactor



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