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SynGest Cornucopia BioRefinery™

"You can have your fuel and eat it too"

The Buzz

I am happy to report that the launch of the SynGest Cornucopia BioRefinery model is getting traction. Since we launched the new approach as part of the keynote address to the 2010 International Biomass Conference in Minneapolis in May, 2010 (along with Till, Baby, Till), I have been interviewed several times specifically on the details. We have also had great reception at USDA and on Capitol Hill. In fact, SynGest will be presenting to the U.S. House of Representatives House Agriculture Committee Staff as well as the agriculture staff of all U.S. representatives on June 22, 2010. We will provide and overview of the Cornucopia model because it is the first integrated BioRefinery processing approach that has the potential to replicate and scale quickly enough to allow the U.S. to achieve all of the RFS2 production goals within the timeframe available. People are getting very excited about the potential.

Cornucopia Overview

The SynGest Cornucopia model takes an entire ear of corn and simultaneously produces The Three F's: food, fertilizer and fuel. This is why we have adopted the slogan: "You can have your fuel and eat it too…". With Cornucopia, there is no more compromise between food vs. fuel…and we get enormous amounts of nitrogen fertilizer in addition. The Cornucopia model is mainly a re-engineering, or re-design, of how we process an ear of corn. When we use the kernels as food, we use them whole which is not ideal for many of the animals that we feed, especially cows. When we make ethanol, we waste the valuable food and the cellulosic parts of the kernel. Also, today, we throw away the valuable cob. The goal is to use every part of the corn plant that can safely be removed from the field year after year. The consensus is that the entire ear is the one part of the plant that meets the criteria for long term soil health. Most agronomy and soil health experts tell us that most, if not all, of the stover must be left on the field. The ear is the target for BioRefinery processing.

Removing The Food vs. Fuel Debate

Today, when we make ethanol from corn, we are not actually making *corn starch* ethanol…but really *whole ground corn* ethanol. Our industry is being done a major disservice when we perpetuate this inaccuracy because it becomes an integral part of the law and other policy. This in turn limits our ability to innovate and craft better outcomes. It may seem subtle, but there is an enormous difference between fuels produced from just corn starch vs. whole ground corn. What we do today with corn and ethanol is the equivalent of taking the whole cow and grinding it all into

hamburger. No one in their right mind would ever do such a thing and waste all of those valuable cuts of meat. However, today that is exactly what we do with ears of corn. A better model is to in effect "butcher" the ear of corn and use each of the "cuts" for its highest and most valuable use. Cornucopia is mainly a re-design of existing systems while deploying some new key technologies that are critical to unlocking the bigger opportunity which is removing the food vs. fuel issue and simultaneously making food, fertilizer and fuel. The key new technology that unlocks the opportunity to do this is SynGest's oxy-blown gasification technology. It is used to produce high yield, low cost syngas for the production of downstream biofuels, bioproducts and fertilizers. Without this technology, the rest of the plan would fall apart.

Technology Overview

There are five technologies that unlock the opportunity for Cornucopia. These are:

1. "Slipstream" biomass harvesting
2. Dry fractionation
3. Fermentation
4. Gasification
5. Food-grade oil extraction

Cornucopia Detail

1. "Slipstream" biomass harvesting is based on the recognition that if we want to harvest large volumes of biomass (which includes cellulose and starch) for biofuel and bioproduct production, we must leverage the enormous farming activity that already exists worldwide. In the U.S., the major crop is corn. The normal harvesting technique is to allow the corn to stand in the field till late in the fall and then use a combine to only harvest the kernels. The model that we have adopted is to simultaneously harvest the kernels and the cobs (partially broken) in the same grain bin. An inexpensive $2,000 modification to the typical combine unlocks this opportunity for the farmer. On the typical farm that grows 180-200 bushels per acre, the farmer will be able to harvest approx. ½ ton of cobs per acre using this technique. This represents about 75% of the available corn cob biomass produced per acre. The approach is to minimize the cost and minimize the change of behavior so as to achieve the highest possible adoption rate. Even though we leave 25% of the potential biomass behind, the net collection is much higher than when we try to achieve perfection in terms of maximum total harvest. Farmers are mainly in the business of growing crops. The sale of crop residue is a sideline and therefore must be made as simple as possible and as fully integrated with the core operation of the farmer's business. This corn/corn cob mix approach achieves both goals. The kernels and cobs are delivered to the grain elevator

together where the cobs are “cleaned” from the kernels and stored separately for later delivery to the BioRefinery. This slipstream approach allows the farmer to participate in a new biomass revenue stream while changing virtually nothing in his normal operation. This approach also leads to the lowest possible cost of collection and hence the lowest possible delivery cost to the BioRefinery. At the same time, when combined with dry fractionation (see below), when the corn kernels are delivered each day to the BioRefinery, approx. 40% of the cellulose needed for the gasifier (also see below) is being delivered in the form of the bran that is the outer jacket of the kernel. Leveraging this source of biomass reflects the epitome of slipstream biomass harvesting.

2. Dry fractionation is also known as dry milling. This is in fact the front end and first processing stage of the entire Cornucopia BioRefinery. The corn kernel is separated into its three main components of corn starch, germ and bran. The starch is sent to the fermenter and the germ is sent to the oil extraction facility. The corn cobs collected as noted above are also delivered and mixed with the residual bran and becomes a mixed cellulose stream for the gasifier (see below). Each component is processed using a different technology to maximize its potential.

   Although these fractionation systems have been around for quite some time, they are just now being deployed in a few ethanol plants. In order to justify the investment, the overall economics must be far superior to making ethanol from whole corn and selling the DDGS as a by-product. In this case, the combined value of the food grade products (oil and protein, see below) are substantially higher than the DDGS. However, unless there is a high value use for the cellulose generated (the bran) and also a low cost way to create food-grade oil and protein from the germ, the return on the investment is sub-optimal. When incorporated as the front end to the fully integrated Cornucopia BioRefinery, the return on the investment in the fractionation technology is maximized because the value of every part of the ear of corn is maximized.

3. The fermentation facility which today is an ethanol plant, efficiently converts the starch into fuel. Fermentation is the most efficient way at our disposal to produce fuel from sugar and starch. The Cornucopia BioRefinery recognizes this and takes advantage of the maturity of this technology. Early rollouts of Cornucopia BioRefinery may in fact include ethanol fermentation as the fuel product. However, as soon as possible, it is recommended that ethanol be replaced by one of the new technologies that produces “drop-in” (fully fleet and infrastructure compatible) fuels. There are a number of offerings that are near-commercial from companies like Butamax, Gevo, Cobalt, Amyris, Optinol etc.

4. The gasification facility is the only really "new" technology in the Cornucopia BioRefinery. The SynGest gasifier, although it has some new characteristics and achieves better performance than prior biomass gasifiers, it is based on well-known and understood technologies. The goal with the SynGest system is to convert any form of biomass into clean syngas at the lowest possible cost and simplest operational approach. The ideal scenario would be to convert biomass into syngas in one step. The best way to come close to achieving that goal is to gasify the biomass using almost pure oxygen and the appropriate catalytic fluidized bed. Although our design gets very close to complete conversion in one step, we still have components of the syngas that need to be handled, such as methane, tars and BTX. In the past, the approach has been to include a "clean up" stage to remove these unwanted gas components. Not only are these clean up approaches costly, they reduce the overall conversion efficiency. The SynGest approach instead adds an autothermal catalytic reformer, also enhanced with oxygen. This second stage of the gasifier converts all of the tar and BTX into syngas and almost all of the methane as well. The net effect is that rather than having a costly clean up stage and a toxic waste issue, SynGest has substituted a low cost yield enhancement device and removed the waste problem in its entirety. This is an example of the proverbial "twofer". It is these elements of the gasifier that have unlocked the potential of using biomass for high value molecule production.

   Efficient production of clean syngas is only one part of the elegance of the SynGest system. By incorporating an air separation plant into the design in order to produce the needed oxygen, a stream of nitrogen is also made available. This nitrogen is required for the production of fertilizer. The SynGest gasifier is self-sustaining and produces biochar and therefore produces GHG-negative products. The production of carbon-negative nitrogen fertilizer is the key element within the Cornucopia BioRefinery that dramatically drives down the overall GHG footprint.

5. Food grade oil extraction is another critical technology to achieve maximum financial and social value of the Cornucopia BioRefinery. The germ fraction is processed in a food-grade oil extraction process. Although there are other techniques in the market, and the historical approach uses hexane (a nasty carcinogen), SynGest has developed a clean and low cost alternative to pulling the oil out of the germ. We use a specific mix of two food-grade solvents (GRAS) that has a natural affinity for the corn oil. The chemical pull of this solvent mix is so powerful that greater than 96% of the oil is pulled out of the germ without the need for mechanical processing. The oil is then easily separated from the solvents which are then recycled and used again for the next batch. The residual of the germ is an already dry and de-oiled high value and high quality protein. This protein can be fed to humans but more importantly can be fed to all of the types of animals that we like to eat. It is fully compatible with the digestive systems of all of these animals and so in

fact is a better feed product than is whole ground corn. Not only can we now make fuel from the starch in the Cornucopia BioRefinery, we are also making enormous amounts of food that is preferable to the unprocessed product. This approach also means that we do not need to burden the GHG LCA of the Cornucopia BioRefinery with indirect land use because that issue goes away. This is definitely an example of "better living through chemistry".

What actually gets Produced

Input. **245,000 acres of corn.**

Fuel. **132 million gallons of fuel.** A typical 110 million GPY ethanol plant, when retrofit to ferment starch vs. whole corn, will produce 20% more fuel per year for a total of 132 million GPY. At the same time, the cost to ferment is lower so a given capital investment will make more fuel at a better margin per gallon.

Food. **71 million Lbs of food grade corn oil and 74 thousand tons of high grade protein.** A 132 million GPY plant as noted above will use approx. 245,000 acres of corn (200 bushels per acre). From that corn, 71 million Lbs of food grade corn oil will be produced and 74 thousand tons of high grade protein.

Fertilizer. **500,000 acres of corn.** Of the bran and cobs, 50,000 tons of anhydrous ammonia (nitrogen fertilizer) will be produced. This will be enough for 500,000 acres of corn or twice as much fertilizer that is needed to fertilize the corn that feeds the Cornucopia BioRefinery. We will be able to fertilize the Cornucopia BioRefinery operation and an equal number of acres beyond for entirely other uses.

Conclusion

The Cornucopia BioRefinery model forces us to re-examine many of the societal and policy biases that exist today. Many people assume that the best way to solve the food vs. fuel debate is to stop using any food products at all or to only expand fuel production with non-food sources . The Cornucopia BioRefinery shows us that a re-design of the system that allows us to produce food, fertilizer and fuel is in fact a better way forward. Also, rather than assume that we can and should unlock the sugars bound up in cellulose and ferment them, Cornucopia BioRefinery shows us that using that cellulose to drive down the GHG footprint via gasification and production of fertilizer, and then using existing highly efficient fermentation technologies is a better way. With the Cornucopia BioRefinery, there is no concern about using large amounts of corn for the production of fuel since we still achieve all of the food value desired, and in fact a better feed. By deploying dry fractionation ("corn butchering") at the outset and then making several high value products from the ear of corn, we can comfortably expand our use of corn to simultaneously meet our food and energy goals. Finally, it is the SynGest gasification technology that

provides the means to make carbon-negative fertilizer which is how we ultimately achieve the majority of the GHG footprint reductions and higher net energy fuel content that we all seek.

Why SynGest's gasification technology is the most transformative…

Given that SynGest's carbon-negative gasification technology and nitrogen fertilizer production is what ultimately unlocks the potential of the Cornucopia BioRefinery, it is clearly the transformative technology of the BioRefinery. Because we can make significantly carbon-negative fertilizer, we are able to lower the GHG footprint of a typical corn crop by more than 50%. When we then allocate the residual GHG footprint to the fractions of starch, oil, protein and cellulose, the fermented fuels become the lowest GHG footprint and highest net energy fuels that we can make today, and will be able to make for the foreseeable future. Rather than using brute force to break down cellulose to ferment fuels, we are using the valuable stored energy in that cellulose to lower the GHG footprint of the starch by mitigating the use of otherwise energy intensive fertilizer. We already know how to ferment efficiently to create biofuels and leverages hundreds of years of technology development and know how. By separating the oil and protein as high value food products we are upgrading our food supply compared to the status quo. This approach is also highly replicable and therefore scalable. We should retrofit our existing fleet of fermentation facilities and embark on a doubling of the national capacity all based around the Cornucopia BioRefinery. It is the only way we know of today that can scale to achieve the RFS2 goals by 2022 in terms of:

(a) total volume of fuel produced,
(b) dramatically lower the GHG footprint of the fuel produced while increasing the net energy and
(c) reduce or remove the food vs. fuel conundrum we experience today.

That is why we believe that SynGest's technology is the most transformative technology not just for 2010, but for many years to come.