

Butanol Agreement

Green Biologics Partners with Easy Energy

In a warehouse containing Easy Energy System's modular biofuels processing system in Emmetsburg, IA, Green Biologics, Inc. is adding a demonstration plant of its own for scaling up its renewable normal butanol process.

Terms of an agreement announced in July will allow Green Biologics (GB) to convert part of the Easy Energy System (EES) facility into a demonstration plant where GB can scale up its Advanced Fermentation Process (AFP) technology producing renewable normal butanol, also known as n-butanol, and acetone as market-ready products.

The agreement grants GB the right to use the EES space for up to six months a year for five years.

Sharing the demonstration plant with EES means GB will spend a fraction of the time and money it would have taken to build a demonstration plant without the existing EES site.

"It's a great opportunity for us," said Patrick Simms, GB's chief operating officer for North America. "We'll spend \$5 million and 8 months building this demonstration plant, which would have cost us \$25 million to \$30 million and 15 to 18 months time if we would have done it on our own."

Start Building

This fall, GB will start building the demonstration plant in the north end of the building that houses EES on Emmetsburg's southwest side.

"Our process allows us to take a dry mill ethanol plant and convert it to butanol production."

- Patrick Simms, Green Biologics

The EES building is just west of the site where POET-DSM Advanced Biofuels, LLC, is building its \$250 million cellulosic ethanol plant called Project LIBERTY. That plant is scheduled to begin operations in early 2014.

GB's demonstration plant is scheduled to begin operation in the second quarter of 2014, Simms said, producing at an annual rate of 150,000 gallons. The new demonstration plant will build on research and development that has been accomplished at GB's 1,100-liter (290-gallon) pilot plant in Gahanna, OH, and its labs in the United Kingdom.

Processing Corn Mash

Last year, GB, which is headquartered in the United Kingdom with a U.S. office in Columbus, OH, produced renewable n-butanol and acetone from corn mash at the Emmetsburg plant at a scale of 40,000 liters (10,567 gallons).

This summer, Simms and four other GB employees have been conducting trials to prove a processing design for the company's AFP. "AFP ferments sugars using our proprietary organism, a type of clostridium with unique properties, to produce n-butanol and acetone," Simms stated. "It's a relatively high-production clostridium strain with other great properties as a commercial strain."

The demonstration plant will allow GB to improve its process, show potential investors and financial entities that the process works, and provide potential ethanol plant clients with an opportunity to visit the site to see the process at work, he said.

"Our process allows us to take a dry mill ethanol plant and convert it to renewable n-butanol production," Simms said.

GB is seeking commercial partners in China, the United States, Brazil, and India.



Left to right: Jesse Wolfe, Easy Energy Systems operations assistant; Jayden Grupe, Easy Energy's operations manager; Oren Webb, process engineering manager for Green Biologics; and Steve Ramey, pilot plant supervisor for Green Biologics; discuss the processing of Green Biologics' renewable n-butanol at the Easy Energy System facility in Emmetsburg.

The company partnered with Laihe Rockley Biochemical Ltd. in Songyuan, China, last year to produce what the company said was the world's first commercial-scale cellulosic butanol and acetone made from corn shells, cobs, and stover.

Chinese Commercial Run

The Chinese commercial trial run was completed in June 2012 at a 3.2 million liter (845,351 gallons) fermentation scale in one of three 50,000-tons-a-year production units.

In November 2012, GB imported 55 tons of the cellulosic n-butanol made in China to the United States, which it is now sampling and marketing for high-value chemical, food, and cosmetic applications.

Simms stated that the 2012 produc-

tion run in Emmetsburg proved that the biology of GB's AFP works. This summer's run at EES has proven that the chemical engineering process of AFP is scalable, he said.

Last year's initial processing run in Emmetsburg went so well, Simms said, that it culminated in the recently-concluded agreement between GB and EES that lasts for a minimum of five years. "This will allow us to scale up our process and operate on a demonstration scale of 500 tons a year," Simms said.

Easy Energy

Mark Gaalswyk, founder and chairman of EES, said that the good relationship that has developed between the two companies means working in tandem shouldn't be a problem for either party.

"The beauty of the relationship with GB is that we can further optimize our Modular Energy Production System

(MEPS) as we help them test their n-butanol production process," he said.

The goal of EES is to build and sell MEPS in sizes of one million gallons a year (MMGY), two MMGY, and five MMGY, Gaalswyk said, and any combination of those three sizes to fit the available supply of feedstock and the type and amount of renewable fuel desired.

MEPS were originally engineered to produce ethanol, Gaalswyk said, but the units have been converted to produce other renewable fuels as well. "What's unique about our system is we integrate a lot of automation technology from Easy Automation," said Gaalswyk.

Affiliated Company

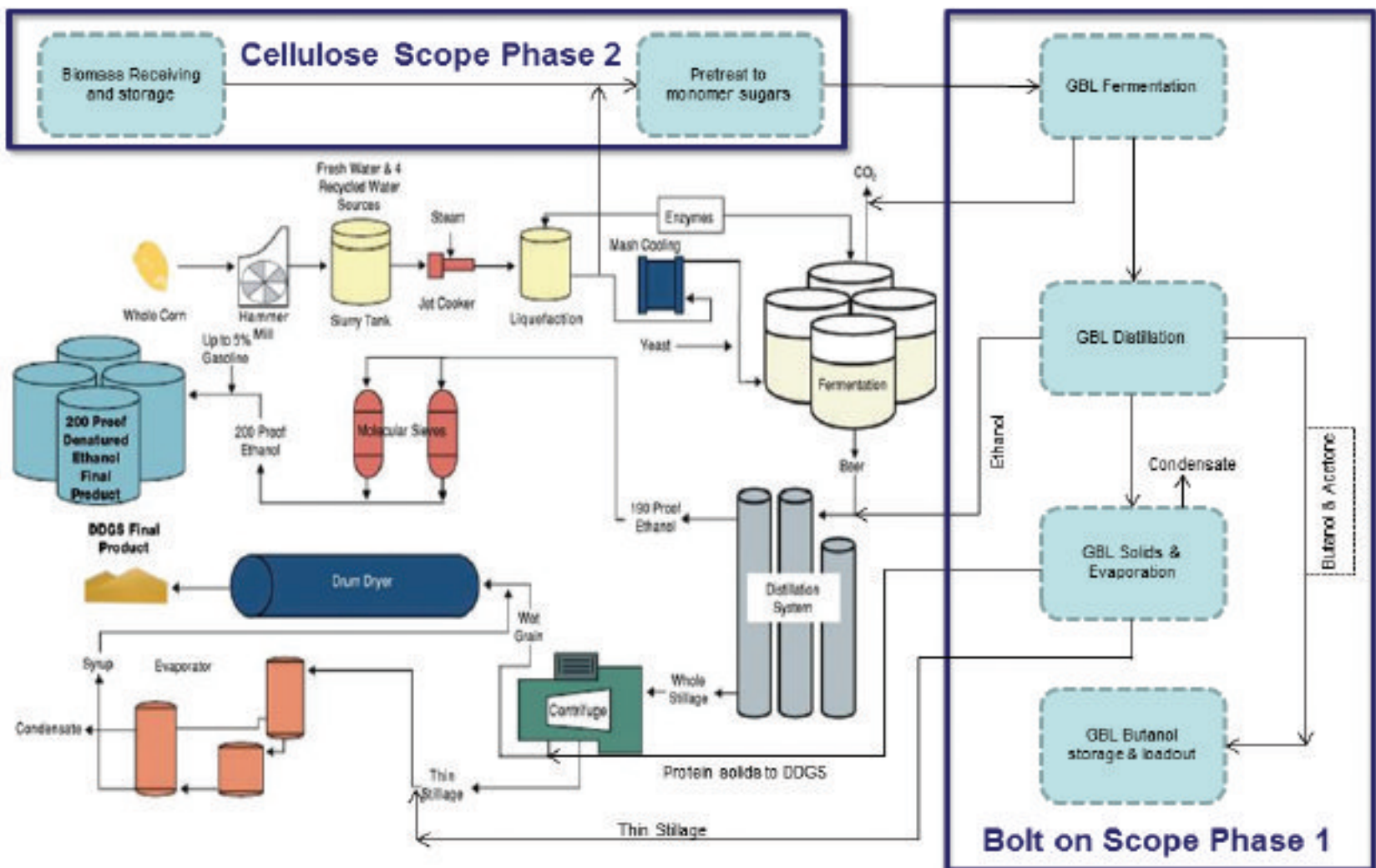
Easy Automation is an affiliated company of EES that also is solely owned by Gaalswyk. Both companies are headquartered in Welcome, MN.



Left to right: Patrick Simms, chief operations officer of Green Biologics; Mark Gaalswyk, chairman and founder of Easy Energy Systems, and Tom Gallagher, sales and marketing manager for Easy Energy Systems, stand in front of one of Easy Energy's distillation pods.

Easy Automation has been in business for more than 25 years in a variety of industries, primarily the milling, feed, and grain industries.

Jayden Grupe, operations manager for EES, said that MEPS has been



Green Biologics' bolt-on turns an ethanol plant into a bio-refinery that can produce both ethanol and renewable n-butanol.

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- Mark Gaalswyk, EES

tested using a variety of feedstocks, including waste paper, corn, milk whey, wheat starch, and waste soda.

The company has built a prototype operating unit that it has been operating since 2010. “We’ve had our concept pretty much in place” since then, Grupe said.

The EES demonstration plant in Emmetsburg has a set of four liquefaction tanks of 1,100 gallons each and two fermentation vessels that can hold 10,000 gallons each. The facility is increasing its number of fermentation tanks to eight. It also has a distillation system and molecular sieve.

High Automation

It is the high level of automation that gives MEPS an advantage, Grupe said. “We don’t use high-pressure steam, so you don’t need boilers or licensed boiler operators, which keeps costs down,” he said.

Another advantage of the MEPS is its small, modular make-up, which allows it to be shipped in container-sized shipments.

It takes six to eight months to manufacture the units, depending on the



Jayden Grupe works at the control screen running the renewable n-butanol fermentation process with software developed by Easy Energy Systems.

feedstock to be used and other options. “We’ll manufacture them in Welcome and Emmetsburg,” he added.

Tom Gallagher, sales and marketing manager for EES, said the company has handled hundreds of inquiries about buying the units, but he declined to talk about specific marketing opportunities.

Cost of the one-MMGY MEPS is \$3.1 million, Gallagher said, from the liquefaction system to the molecular sieve.

Simms said that EES will help market the GB process with MEPS, which could be a niche market in the rural United States or in developing countries where available supplies of feedstocks might be inadequate for supporting production at a large-scale plant.

Building Block

Joel Stone, president of Green Biologics Inc., the U.S. arm of GB Limited, said that n-butanol is a building block in paints, coatings, adhesives, and inks, an \$85 billion global market.

“The n-butanol chemical market is around \$8 billion globally,” Stone said, “at least 10 times that of isobutanol.”

Argonne Labs has demonstrated that n-butanol can be blended into diesel fuels at a 30% to 40% ratio, according to Stone. Because n-butanol has octane ratings nearly identical to gasoline, he stated, it can be blended at any ratio with gasoline or used in place of gasoline.

Isobutanol does enjoy a fuel blend advantage over n-butanol because of its higher octane content, Stone said, but he noted that n-butanol and isobutanol have essentially identical energy content.

Timothy Staub, GB’s vice president of business development, said that in addition to paints, coatings, adhesives, and inks, n-butanol also is used in the plastics and polymers industry and in specialty end uses in food ingredients, food flavorants, personal care products such as cosmetics and fragrances, pharmaceuticals, and nutraceuticals.

The global market for butanol is growing at more than 4% a year, he said.

In China, where GB made its first commercial-scale renewable n-butanol production run, the market is growing by 9% a year, Staub said.

Stone said that retrofitting or adding a bolt-on to ethanol plants so that they can use GB’s process to make renewable



Vennie Tee, fermentation scientist with Green Biologics, prepares a fermentation seed culture for processing.

n-butanol can turn those facilities into biorefineries producing and selling high-value chemicals rather than low-margin fuels. “Adapting the GB technology allows plants to transition to higher-value markets,” he said. “The Emmetsburg demonstration plant can show them how they can move aggressively forward.”

GB is in discussions with a number of ethanol producers, Stone said, about retrofitting under-performing ethanol assets with the GB technology to produce n-butanol or adding a bolt-on GB n-butanol plant adjacent to a large ethanol plant to simultaneously produce both n-butanol and ethanol from corn or cellulosic feedstocks or both.

GB is pursuing a dual marketing strategy, he said.

Option one calls for GB to retrofit an existing ethanol plant to produce n-butanol and acetone, co-investing with the plant owner or other investors.

Option two calls for GB to build a new plant adjacent to a large ethanol plant and co-invest in the new plant in partnership with the current owner.

In both options, GB plans to operate n-butanol facilities and market the n-butanol and acetone output.

“Our business model creates the foundation for a true biorefinery using multiple feedstocks to produce a range of high value fuels and chemicals from both C5 and C6 sugars so it can run on corn stover, wheat straw, wood chips, or other feedstocks, which opens the ►



Steve Ramey's 2001 Harley Davidson 1200 custom motorcycle has been run on 100% n-butanol.

door to the next generation of true bio-refineries in North America," Stone said. "Rather than have a corn-based plant that produces ethanol, we can turn the ethanol plant into a chemical bio-refinery and produce chemicals that have a higher value."

Formed by Merger

Green Biologics, Inc. grew out of a January 2012 merger between Green Biologics Ltd. (GBL), a UK-based industrial biotechnology company, and

Butylfuel™ Inc., an Ohio-based renewable chemicals and biofuels company.

Stone, who was chief executive officer of Butylfuel at the time of the merger, said each company brought its own strengths to the combined company. GBL is a world leader in clostridia biology with more than 300 strains of clostridia that it had optimized through research and development. With that diversity, GB can select the best clostridium for a particular feedstock and fuel, he said.

Butylfuel's strength that it brought to the merger came from its efforts at the laboratory bench and scaling those efforts to commercial products. "Our base platform was the commercial strength on large-scale fermentations and the scale-up that we had done at our pilot plant in Ohio," Stone said.

GB's AFP platform combines the unique clostridia strains and their stability with solid biochemical operations for higher productivity, he stated. "AFP allows us to at least double the productivity of butanol fermentation," Stone explained. Fermentation productivity



Green Biologics will install new distillation equipment for renewable n-butanol and acetone adjacent to Easy Energy's existing distillation unit.

has historically been a significant challenge for butanol processing, he added.

Jerry Perkins, editor

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