Renewable energy solutions for an energy hungry world

Biofuels that can compete in a low priced oil market

By: Gary Luce

For more than 40 years, every U.S. President has vowed to support measures to secure America's energy independence. But in spite of years of research and billions of dollars invested, oil continues to supply approximately 95 percent of America's liquid transportation fuels and 73 percent of that supply is imported.

The Obama-Biden administration has promised to spend $150 billion over the next 10 years for the development of alternative energy and has vowed to provide the tax incentives and federal resources to ensure development of the next generation of sustainable biofuels and the infrastructure needed to produce them. However, in today's precarious economy with its wildly fluctuating oil prices, the question is whether that campaign promise will be fulfilled.

Terrabon believes that it is critical for America to develop renewable energy solutions to meet the world's growing hunger for energy—solutions that are competitive when market prices are low and provide a reliable source of low-cost fuels when oil prices skyrocket. For the country to be truly energy independent, it is essential that we create technologies that bring biofuels to every corner of our country, including smaller municipalities and rural areas. Even more important, these technologies must be simple and cost effective to use.

For more than 15 years, Terrabon has been working to develop a biofuels solution that meets those criteria. Since 1995, we have funded development of MixAlco™, a unique acid fermentation technology that converts readily available, low-cost biomass into chemicals that can be processed into renewable gasoline.

It is a simple technology that was inspired by the digestive system of the ordinary cow. Cows generate energy by converting biomass to organic acids. When a cow eats grasses, it also picks up a mixed culture of micro-organisms in the soil that combine with other fluids to convert the biomass into the cow's energy requirement. Dr. Mark T.

Holtzapple and a team of researchers of Texas A&M University took on the challenge of how to take this process, which has been thermodynamically optimized by nature for thousands of years, and develop an engineering process to make it efficient and cost competitive on a commercial scale.

The process works like this. The biomass is pretreated with lime and oxygen to enhance digestibility before being fed to a mixed culture of acid-forming microorganisms derived from a saline environment. The acids are neutralized with either calcium carbonate or ammonium bicarbonate, thus forming carboxylate salts. The carboxylate salts are concentrated using vapor-compression evaporation before being chemically converted to an array of products.

Unlike other biofuels produced from food crops, MixAlco's carboxylate platform uses already collected feedstocks that are either being sent to a landfill or used for low-priced, nonfood applications. MixAlco uses any ordinary form of biomass such as municipal solid waste, sewage sludge, manure, agricultural residues and non-edible energy crops. The biomass is placed in a large, oxygen-free tank, similar to the rumen of cattle, where naturally occurring organisms convert the biomass to vinegar. No sterility is required and no enzymes must be added.

A perfect example of a "biorefinery," a wide variety of chemicals and fuel products may be produced using the MixAlco technology, such as ketones, carboxylic acids, esters, ethers, aldehydes, primary and secondary alcohols, aromatics, cyclic, olefins and fuels such as gasoline, jet fuel and diesel. The vinegar produced can be sold directly into the chemical market to make plastics or it can be converted into other chemicals such as acetone. By adding a small amount of hydrogen, alcohol fuels can be made that have higher energy content than conventional ethanol. The alcohols can be converted to gasoline that is virtually identical to conventional gasoline made from crude oil.

A key objective of MixAlco's low-cost process is to produce a very dense, liquid, carboxylate salt and water mixture, or bio-crude, near the feedstock source in small, decentralized fermentation operations. The liquid bio-crude would then be transported to a large central biorefinery for further refining, such as esterification and/or hydrogen addition for making renewable gasoline. This allows smaller plants to be located at the source of the feedstock, making the technology especially attractive to municipalities for

turning relatively small amounts of municipal solid waste and sewage into renewable gasoline.

MixAlco's scale and economics makes it a viable energy solution for smaller cities and rural communities both in America and in countries throughout the world. With its green carbon footprint, feedstock flexibility and lower capital costs, MixAlco provides the ability to build low-cost, smaller plants closer to existing biomass sources.

Initially, Terrabon plans to form joint ventures with municipalities with populations of 100,000 to 150,000 in which we would install 200-ton per day facilities producing about 4.5 million gallons of renewable gasoline annually at a cost of approximately $1.35 per gallon. This scenario provides a win-win solution. The municipality would serve as Terrabon's feedstock partner and would also assist with access to land and permitting. In return, the city would save on disposal costs of municipal waste and receive an economic return once the project capital has been repaid. We also intend to license the technology to specific sites where the resources are available to appropriately construct and operate the technology.

We believe this approach will set the standard for a distributed pretreatment and fermentation system that will allow us to respond to the logistical challenges associated with large-scale biomass fuel production. This technology can also be deployed on a large scale of more than 1,000 tons per day using energy crops such as sorghum or the residual crushed algae carcasse.

Until now, the cost of developing and producing reliable biofuels has been high. The economics of MixAlco, however, require lower conversion costs for both large and small-scale applications. When this technology is applied to municipal solid waste and sewage sludge feedstock, we estimate the cash cost of production for renewable gasoline to be less than $33.00 per barrel. If incentives are provided by the federal government in the form of tax credits, the effective cash cost of production could be well below $20.00 per barrel.

For the past three years, the MixAlco technology has been tested at a pilot plant in College Station, Texas. We recently completed construction of Energy Independence I, our Advanced Biofuels Research Facility in Bryan, Texas, that will confirm the scaled-up feasibility of MixAlco. The semi-works demonstration plant will have a loading capacity

of 400 dry tons of biomass using sorghum as the primary feedstock. The intermediate product of carboxylate salts from the facility will be sent to the reconfigured pilot plant to be converted to renewable gasoline at a rate of 300 - 350 gallons per day.

Speaking at dedication ceremonies for the facility in November 2008, Texas Governor Rick Perry encouraged investment in researching and marketing alternative energy sources such as MixAlco as a method for moving Texas and the nation toward energy independence. "Energy independence has become a critical goal as the worldwide demand for energy continues to rise, and traditional energy sources can no longer be solely depended on to provide the resources needed," he said. "To advance the next generation of energy technologies, we must continue to develop and refine new ideas and take some risk to produce and market them through innovation and competitive markets. This is ultimately how we as a state and a nation will advance the next generation of energy technologies."

Advancing the next generation of biofuels technologies is critical—not only in meeting the growing need for new energy resources, but in providing new opportunities for farmers with new energy crops and in revitalizing the economies of our smaller municipalities and rural communities via the conversion of municipal solid waste and sewage sludge to a viable transportation fuel. As we go forward, we hope the new administration will make good on its campaign promise to invest in innovative technologies and will be open to the new ideas that will create renewable energy solutions for our energy hungry world.

Gary W. Luce is Chief Executive Officer of Terrabon, L.L.C. Mr. Luce has more than 25 years of senior management strategic planning and operating experience in the energy sector, and since June 2007, he has been the principal architect of Terrabon's technology deployment. Prior to joining Terrabon, Mr. Luce cofounded K-L Energy Partners, LLC, which focuses on investments in the midstream and downstream sectors of the energy industry. He also served as Group Senior Vice President with Reliant Resources, Inc., where he was responsible for greenfield development projects, as Interim President, Executive Vice President, and as a Senior Vice President with EOTT Energy Partners,

LP, and as a Practice Principal and Senior Engagement Manager with McKinsey & Company. He graduated summa cum laude from Texas A&M University and Stephen F. Austin State University with degrees in chemical engineering and physics and received an MBA from Houston Baptist University.