Reshaping American Energy–A Look Back at BETO's Accomplishments in 2013

The U.S. bioindustry provides a secure and growing supply of transportation fuels, biopower, and bioproducts from a variety of biomass resources. Biomass is the only renewable energy source that can offer viable substitutes for petroleum-based liquid transportation fuels in the near term. It can also provide valuable chemicals for manufacturing and power to supply the grid. For more than a decade, this important industry has been shaped by the efforts of the Bioenergy Technologies Office (BETO). BETO helps sustainably transform our renewable biomass resources into commercially viable, high-performance biofuels, bioproducts, and biopower through targeted research, development, demonstration, and deployment.

In 2013, there have been some significant accomplishments leading toward establishing a fully commercialized, robust, domestically sourced bioindustry. These efforts cover the full range of technology areas in BETO's portfolio.

Putting the Pieces Together: BETO Reaches New Heights in Cellulosic Ethanol Advancement

In the fall of 2012, scientists at the U.S. Department of Energy's national laboratories successfully demonstrated—at significant scale[1]—two cellulosic ethanol production processes at a cost of $2.15 or less per gallon; these processes included both feedstock harvesting and transportation and integrated conversion steps. Nearly a decade of dedicated research and development supported this achievement, facilitating in 2001 a rapid reduction in cost from more than $9 per gallon in 2001. Teams at the National Renewable Energy Laboratory, Pacific Northwest National Laboratory, and Idaho National Laboratory (INL) overcame significant barriers and reduced production costs and inefficiencies, bringing the nation one step closer to a stable, affordable supply of cellulosic biofuels.

The laboratory teams focused on three primary areas to reach this goal: harvesting and feedstock supply system logistics; biomass pretreatment and enzymatic hydrolysis followed by fermentation; and gasification followed by syngas cleanup and fuels synthesis. In harvesting and supply logistics, advances were made that enabled better regional assessments of feedstocks available and associated costs, improved the longevity of biomass in storage for transport, and developed more energy- and cost-efficient preprocessing techniques to deliver

Scientists at U.S. Department of Energy's national laboratories demonstrated two cellulosic ethanol production processes at a cost of $2.15 or less per gallon, bringing the nation closer to a stable, affordable supply of biofuels. *Photo courtesy of NREL.*

the right feedstock to the reactors. In biochemical conversion, key breakthroughs involved developing improved enzymes that reduced costs of sugars released from the biomass and more resilient and efficient fermentation organisms that can achieve higher ethanol yields. In thermochemical conversion, the team optimized an indirect steam blown gasifier, developed tar and methane reforming technologies, and vastly improved catalytic conversion technologies that create syngas. All of these efforts came together at a process demonstration unit, where data was collected and, when modeled, resulted in a projected commercial-scale cost of $2.15 per gallon from corn stover and $2.05 per gallon from woody feedstocks.

Demonstrating this target has far-reaching impacts; lower production costs encourage private-sector investment in the cellulosic ethanol industry. Some of the first BETO-sponsored biorefineries are opening their doors for commercial production this year. Combined with this demonstration, the financial community will have more confidence to build out an industry that will ultimately increase U.S. energy security and cut costs at the pump.

Improvements in the Field: Meeting the Feedstock Milestone

Meeting the nation's fuel and energy needs starts in the field or the algae pond; a consistent supply of high-quality biomass is necessary to keeping the bioindustry on the go. That is why BETO invests in a variety of projects that improve the quality of crops grown and the methods used to harvest and process them. In the last year, a partnership between INL and Iowa State University (ISU) achieved the feedstock milestone for producing feedstock from corn stover for less than $35 per dry ton. This critical target enables biofuels to compete economically with petroleum-based fuels from the beginning of the process. The INL-ISU team

Another one of BETO's accomplishments this year includes a partnership between INL and Iowa State University that produced feedstock from corn stover for less than $35 per dry ton. *Photo courtesy of Idaho National Laboratory.*

collaborated to effectively harvest, bale, and store the corn stover before transporting it and preparing—or preprocessing—it for use in a biorefinery (touching on and improving every facet of the supply process).This critical achievement outlines best practices that could be replicated with a variety of feedstocks to lower the cost of biofuels and bioproducts, and provided invaluable support in achieving the cellulosic ethanol cost target.

Game Changers: Improved Yeast, Bacteria, and Enzymes Propel Conversion Technologies

BETO has partnered with several companies to develop improved strains of yeast and bacteria that convert lignocellulosic biomass sugars into biofuels. Two of BETO's project partners, DuPont and Mascoma, have developed commercially viable strains that they will soon implement in their own biorefinery operations. By requiring these partners to meet stringent validation standards, they were able to demonstrate the quality of their products to other interested investors and buyers. During this same period, BETO partnered with Novozymes, Cargill, Purdue University, Genencor, DSM, and Verenium to improve the performance and cost effectiveness of enzymes that process lignocellulosic-based sugars. By performing to the Office's rigorous standards, each of these partners was able to make significant improvements in their development processes, which they still utilize for their independent, commercially available products.

Primed for Production: Integrated Biorefineries Operating in Four States

BETO supports a number of integrated biorefineries that are specifically focused on producing cellulosic ethanol. As of mid-2013, three biorefineries have opened or are nearing completion, while two others have started construction. Among these are the first commercial-scale cellulosic ethanol plants in the country, in the country—realizing a major BETO goal.

- POET and Abengoa began construction in 2013 with an anticipated startup in 2014. Together, these two facilities will have an ethanol production capacity of more than 50 million gallons per year.
- INEOS completed construction of its demonstration-scale waste-to-fuel biorefinery in Vero Beach, Florida, in early 2012. Later that year, the facility officially began production of cellulosic ethanol and biopower. When it reaches full operational capacity, it will produce 8 million gallons of advanced biofuels and 6 MW of renewable biomass power per year from renewable biomass, including yard, wood, and vegetative wastes. As of July 2013, INEOS has been producing cellulosic ethanol at commercial scale, with the first fuel shipments that was released in August. Throughout the course of its construction, it has created nearly 400 jobs, sourced 90% of its equipment from U.S. manufacturers across 10 states, and provided more than $4 million annually in payroll to the local community.[2]
- Logos and EdeniQ completed the start-up and commissioning of a pilot-scale biorefinery in October 2012, relying on American Recovery and Reinvestment Act of 2009 funds to retrofit EdeniQ's plant in Visalia, California, to enlarge the facility to an annual production capacity of 50,000 gallons of cellulosic ethanol. Once the Logos-EdeniQ plant has demonstrated its processes, it will gradually scale up to a commercialized level.
- Myriant has used BETO funding to develop a process to produce bio-succinic acids in its facility in Lake Providence, Louisiana. The facility will produce 30 million pounds of bio-succinic acid per year, commercializing a renewable, environmentally friendly alternative to a valuable production chemical. After opening earlier this year, Myriant has been exploring the field of biochemicals, reducing their environmental footprint with no impact on the product's performance.[3]

[1] With conservative economic assumptions and proven process parameters, the technologies demonstrated at pilot[1] scale are modeled to produce cellulosic ethanol at commercial scale cost that are competitive with gasoline production at $110 per barrel of crude oil. Pilot[1] scale is defined as biomass "throughput ≥ 1/2 dry tonne per day."

[2] INEOS Bio Facility in Florida Begins Producing Renewable Power, INEOS Bio, 31 October 2013. http://www.ineos.com/en/businesses/INEOS-Bio/News/INEOS-Bio-Facility-in-Florida-Begins-Producing-Renewable-Power/.

[3] Flagship Commercial Facility in Lake Providence, Louisiana, Myriant, March 2013. http://www.myriant.com/media/press-kit-files/Myriant-LPFactSheet-0313.pdf.

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