CATF WHITE PAPER:

Corn Butanol: Gevo's Technology, Economics, and Performance

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TECHNOLOGY

Gevo's business involves production of isobutanol for sale as both a fuel additive and a chemical feedstock. The Gevo Integrated Fermentation Technology (GIFT) platform involves two steps: a biocatalytic process that coverts sugars from renewable feedstocks into isobutanol through fermentation and a process that continuously separates isobutanol during the fermentation process.

According to a recent Gevo prospectus, the company has "developed our technology platform to be compatible with the existing approximately 23 billion gallon per year (BGPY) of global operating ethanol production capacity".[1] The GIFT technology is clearly slated to be adaptable by existing ethanol refineries, in order to produce butanol from corn sugars.

Gevo requests advanced biofuel certification using a net carbon analysis that is based upon a specific project. This project involves the partial conversion of a Minnesota ethanol refinery to butanol production using the GIFT process. Corn mash will provide the sugars for fermentation. In this instance, Gevo proposes to build an anaerobic digester/generator combination that will supply most or all of the plant's internal gas and electricity needs, and it is on the basis of the energy contributed from this digester and associated generator that the life-cycle carbon impacts of the resulting product falls below the advanced biofuel carbon threshold. The digester would use weak stillage from the ethanol refinery as its main input. Based on CATF discussions with Gevo, it is not clear whether this will provide sufficient input or whether supplemental biomass will be needed[2]. Without the addition of renewable gas and electricity, the resulting product would not meet the threshold for an advanced biofuel, but would be only marginally better than ethanol. Therefore, subsequent applications to qualify isobutanol produced through the GIFT process would also need to include a renewable gas and electricity component to meet the RFS2 threshold.

An approval of the Gevo proposal could persuade existing ethanol producers into retrofitting the GIFT technology and converting somehow to renewable fuel and electricity. Could an ethanol producer purchase green electricity from a local provider and renewable bio-gas from a nearby anaerobic digester? Such arrangements are both physically and economically possible, and conventional life cycle analysis would assign the same credit for energy generated outside the project fence as inside it. Gevo clearly has its sights set on the ethanol retrofit market, so the prospects for wider adoption of the technology—especially if advanced certification is awarded—seem good. Gevo's most recent stock prospectus provides the following estimate of the market size (emphasis added):

[1] GEVO, INC, Prospectus Supplement, December 13, 2013.
[2] CATF teleconference with Gevo staff, May 2014

> "We believe that products derives from isobutanol have potential applications in substantially all of the global hydrocarbon fuels market, **representing a potential market for isobutanol of approximately 1,000 billion gallons per year** …"[3]

On July 18, 2014 the US EPA declined to take final action on Gevo's request to certify isobutanol as advanced biofuel. Gevo has not yet reported the EPA action in its recent SEC filings. We must conclude that the company regards this as an open issue, and intends to continue to press for certification. If the EPA ultimately turns down Gevo's request, the market for its butanol—and for its GIFT process—will be much smaller. It is at least clear that certification as advanced biofuel would provide a very significant boost to Gevo's prospects.

GEVO'S FINANCIAL STATUS

As with almost all development stage companies, Gevo is strapped for cash. In addition to a series of debt financings, Gevo went public with an IPO in 2011, at a price of about $20 per share. Currently, Gevo is trading at less than $0.50 per share, and is in danger of being delisted from the NASDAQ. Gevo has issued two new blocks of stock in the past 6 months. This stock is being used to defer debt repayment. In addition to diluting the value of the company for current shareholders, the offering gives buyers future stock warrants that can be exercised if the Gevo share price recovers from its current lows. Gevo's auditor recently warned that the company is in danger of insolvency. The two stock offering will raise about $30 million; this will not carry the company much past the beginning of 2015.

ECONOMICS

Gevo estimates that converting an ethanol refinery to use the GIFT process costs in the neighborhood of $1/gallon.[4] The University of Illinois, in its farmdoc daily website estimates that a 100 million gallon per year (GPY) ethanol refinery has capital costs of around $2/gallon.[5] Thus the addition of the GIFT process would increase the initial capital requirement by 50 percent.

The anaerobic digester/generator combination will also add capital costs to the existing ethanol refinery. In 2007, US DOE estimated that adding combined heat and power systems (CHP) at gas-fired ethanol refineries would typically require about $20 million in capital.[6] A CHP project would increase capital costs by about 10 percent at a 100 million GPY ethanol plant. The DOE study suggested that the CHP project would payback over time through avoided natural gas and electricity purchases. However, at the time DOE assumed that natural gas prices would be between $7 and $8 per MMBtu, which is much higher than present levels.

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[3] Gevo Inc, Prospectus Supplement, to prospectus dated May 15, 2013, July 31, 2014, S-1.
[4] Gevo, op. cit.
[5] Farmdoc Daily, June 14, 2013 (http://farmdocdaily.illinois.edu/2013/06/updated-profitability-ethanol-production.html).
[6] RESEARCH INVESTIGATION FOR THE POTENTIAL USE OF COMBINED HEAT AND POWER AT NATURAL GAS AND COAL FIRED DRY MILL ETHANOL PLANTS, prepared for the US Department of Energy, November 2007 (http://www.erc.uic.edu/assets/pdf/ethanol_doe_project.pdf).

In combination, the GIFT process plus renewable gas and electricity production would increase the capital requirements at a 100 million GPY ethanol refinery by about 60 percent. There would be additional operation costs associated with the CHP facility, which would be offset somewhat by savings on conventional natural gas and electricity.

The value of isobutanol at around $2400 per metric ton is significantly greater than gasoline, at around $1,000 per metric ton.[7] However, the cited figure is for isobutanol used as a chemical feedstock, not as a gasoline additive. It is unclear what economic value isobutanol would fetch as a fuel additive. Isobutanol has a higher heat content than ethanol and has better handling properties, so some premium would probably be available. Whether it would be sufficient to offset the additional capital and operating costs is unclear.

It is also unclear what incentives oil companies would have to purchase isobutanol—in spite of its superior characteristics—over the less expensive ethanol, which they already handle and blend with success.

It seems clear that certification as an advanced biofuel is essential for Gevo's isobutanol to compete as a fuel additive. As pointed out above, if Gevo is granted advanced biofuel certification for its corn-based isobutanol, the incentives for other ethanol retrofits seem very good.

OTHER RISKS TO THE GEVO PROCESS

Process Contamination. The GIFT process commenced operation at the Minnesota plant in 2012. It was later shut down for an extended period of time due to process contamination issues. The unit has now been restarted, and Gevo hopes to achieve complete conversion by the end of 2014. However, Gevo plans to maintain the ability to fall-back to ethanol production should it encounter problems with the GIFT platform, indicating that the company is less than fully confident in the process at this point.

IPR Dispute. Gevo is involved in protracted litigation with another isobutanol producer, Butamax (a company owned by the petroleum giant, BP, among others), over alleged patent violations. If Gevo is found to have infringed Butamax patents, it could have a significant impact on Gevo's commercial success.

Alternative Conversion Technology. Research published in 2013 demonstrates at the lab scale a process for converting ethanol to butanol. The authors of this study estimate that the plant conversion cost of this approach would be $10-$15 million (in contrast to $100 million for the GIFT platform). If this process is proven at commercial scale and the cost estimates are accurate, it would be difficult for the GIFT platform to compete against.

LIKELIHOOD OF A CORN STARCH BUTANOL SCALE-UP

If the following conditions are present a scale up in corn-based butanol could occur:

[7] Seeking Alpha, July 30, 2012 (http://seekingalpha.com/article/761591-why-biofuel-energy-corp-investors-are-so-excited-about-isobutanol).

- EPA certifies the Gevo pathway (or perhaps the Butamax approach) as an "advanced biofuel;"
- Low carbon electricity and biogas are available at existing refineries either through retrofit or purchase; and
- The combined capital and operating costs of the GIFT retrofit and the CHP unit are offset by the expected price for advanced biofuel RINs and energy savings; or the capital and operating costs of the GIFT retrofit in combination with purchases of zero carbon electricity and biogas are offset by the expected price for advanced biofuel RINs and energy savings.

The latter possibility is especially concerning. According to discussions with Gevo staff, EPA has indicated that low carbon energy from outside the fence cannot be used. We see little basis for such a policy. EPA has made life-cycle analysis (LCA) the basis for much of its biofuel policy. It is well within the accepted bounds of LCA to include energy that has been purchased or self-generated, and EPA policy to the contrary would appear arbitrary and inconsistent. If EPA approves the Gevo pathway, we could see ethanol refineries retrofitting the GIFT process and purchasing wind power and biogas from existing producers. This would result in a rearranging of existing commercial arrangements, but no meaningful shifts in environmental performance.

Although it is always a challenge to raise capital, the incremental investment needed to convert existing ethanol refineries could be justified on the basis of the looming blend wall and associated risks in the conventional ethanol market along with the expected prices for advanced RINs. If the Gevo pathway is approved, conversion of even a small amount of existing ethanol capacity to produce isobutanol could flood the advanced market with a product whose inputs are essentially no different from conventional ethanol and whose characteristics have little in common with the current vision of advanced biofuel. Given the lack of real advanced biofuels and EPA's continuing need to adjust advanced biofuel targets substantially downward, an EPA approval could easily stimulate a flood of capital into existing ethanol plants, and an advanced market saturated with corn-based isobutanol.