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Will New Technologies Preserve Minnesota's Ethanol Industry?

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One of the great economic development success stories of the last decade has been Minnesota's financial and political investment in the corn ethanol industry. Starting from a base of essentially zero production in the late 1980s, the state helped create an industry that today produces over a billion gallons of ethanol each year and employs over 1,000 workers.

But the desirability of continuing this success story has recently been called into question. The environmental performance of corn-based ethanol has been challenged at a time when the industry is struggling financially. We are also hearing about a host of technologies that are said to be capable of profitably making biofuels from non-grain feedstocks and at the same time deliver better environmental performance than the plants that are now operating.

In this article we discuss how emerging political and technological developments in this important industry might affect Minnesota communities.

A long history of state and federal industry support

Over the years, we've seen a great many policy goals attached to corn-based ethanol, including energy security, local economic development, improved environmental quality, and (only very recently) reduced greenhouse gas emissions.

Public support for corn grain ethanol dates back at least to the Carter administration, as the nation faced higher crude oil prices caused by supply restrictions by OPEC. This resulted in significant early investment in alternative energy technology improvements, among them corn ethanol. The energy independence argument, made in the 1970s and made again today, is valid: the more ethanol we produce, the less foreign oil we need to import. But the net effect is modest at best, given current technologies. Too, the foreign oil that Minnesota imports and that we're trying to replace is largely from Canada, not from the Middle East. Whatever its validity, the fact remains that with the early 1980s drop in oil prices came an abandonment of the goal of developing alternative domestic sources of transportation fuel, taking with it the economic fortunes of many small ethanol producers who could no longer compete with oil.

Minnesota followed a decade later with a simple direct subsidy per gallon of production, paid to the operators of the ethanol plant. The subsidy was 20 cents per gallon, up to a maximum of 15 million gallons per year — at the time a typical ethanol plant capacity. (Since 2003, nearly all new plants have been rated at either 50 million or 100 million gallons per year.) The subsidy was credited with helping early ethanol start-ups by providing some comfort of state support for these fledgling businesses.

Environmental goals started to replace energy security and economic development goals when the federal government began enforcement of the Clean Air Act. By 1995, the use of oxygenates became important as gasoline was modified to burn more cleanly in urban settings to reduce health effects of tailpipe emissions. Ethanol works well as an oxygenate and also serves to increase the octane of gasoline. However, the petroleum industry favored an oxygenate they could produce (i.e., methyl tertiary butyl ether [MTBE]) from relatively cheap natural gas and from the by-products of petroleum refining. In contrast farm states like Minnesota actually mandated that ethanol be the oxygenate of choice over MTBE.

The increase in demand led to a sizable and persistent price premium for ethanol compared to gasoline. This was accompanied by a major state decision to require that all gasoline sold in Minnesota be blended with 10% ethanol year round, after a period when federal carbon monoxide standards required oxygenated gasoline during the winter months. The creation of a year-round market represented an enormous boost for ethanol demand, most of which was met by Minnesota producers.

The most recent boom in ethanol production began in 2005, when MTBE was banned by numerous states and when the Energy Policy Act of 2005 failed to grant the manufacturers of MTBE liability protection from environmental damage and health claims.

Even more recent demand enhancement came in the form of the federal renewable fuels standard (RFS) requiring that a stated (and increasing over time) proportion of U.S. motor fuel consumption be in the form of "renewable" fuels, which could only be accomplished by production of corn ethanol and to a much lesser extent with biodiesel.

Big changes in ethanol's economic and policy world

Two new stressors have appeared in recent years. One is driven by a concern about global climate change, and one is driven by concerns about the underlying economics of the corn ethanol industry itself.

Before we focus on the industry's financial prospects and speculate upon their effects on local economies, let's consider how ethanol fits into Minnesota's stated intent of reducing greenhouse gas emissions from motor fuel combustion.

Both the Governor and the Legislature have set ambitious greenhouse gas (GHG) reduction targets. Because corn grain ethanol and other biofuels are biological systems, it is clear that to some extent any greenhouse gases emitted when ethanol is burned in our cars are offset by the "sequestration" of the same gases when the corn plant is growing. So, when we compare the "greenhouse footprint" of ethanol to that of gasoline, we take into account the amount of carbon dioxide that is removed by the next year of growing corn plants and contained in their tissues. As a result, ethanol has a calculated lower amount of net carbon dioxide emissions than a fossil fuel like gasoline, which results in the dispersion of a substantial amount of geologically "old" carbon from crude oil.

However, recent research has resulted in a substantial shift in the way that GHG scoring is conducted. In previous "life-cycle analysis" — the scoring of fuel emissions from all emissions at the farm, in transport and at the fuel plant, as well as at the tailpipe of our cars — resulted in ethanol scores being lower than gasoline. However, if we also take into effect — as the federal government recently proposed — the so-called indirect land use change effect, the effect on ethanol could be dramatic.

The indirect land use effect is a subtle and hard-to-measure concept. In brief, it holds that increased U.S. ethanol production leads to increased corn demand, which shows up in markets as higher prices for corn. That, of course, was one of the initial arguments proposed in favor of ethanol industry subsidies: the rise in local corn prices, which farmers, of course, support.

However, what if the higher corn prices lead farmers, whether in the U.S. or elsewhere, to plant more corn? And what if the land they plant to corn was previously grassland or forest? Plowing up grassland and cutting down forests for corn has an undeniable immediate effect on GHG emissions, which rise in the immediate aftermath of land conversion and would require years or decades of grain production for biofuels and attendant reductions in GHG reductions to overcome.

This has become a major policy issue. Should fuel-scoring take indirect land use change into account? Should ethanol be "blamed" for all of these emissions? And if it should, how do we measure such an elusive concept?

A just-released federal regulation proposal answers the first question by saying: yes, we should take indirect land use change into account. Depending upon the economic/engineering technique that is applied, the indirect land use factor, when combined with all the other LCA scores for ethanol (planting, harvesting, shipping, processing), can make ethanol look *worse* than gasoline.

If this proposal becomes law, then the effect on grain ethanol demand could be substantial. Lower demand and resulting lower prices would be a harsh blow to Minnesota's ethanol industry.

In addition to arguing directly against the proposals to include indirect land use change in the first place and against the particular scoring system the federal government has proposed, the ethanol industry has also taken steps to demonstrate that the current system does not accurately reflect the "true" GHG profile for corn ethanol, at least in Minnesota. If successful, this argument might so reduce the score for corn ethanol that it would end up lower than gasoline even if indirect land use change is included.

The second step is to encourage the development of new ethanol technologies such as cellulosic ethanol that rely not upon corn grain as a feedstock, but upon other plant materials. This leads us to our second major industry development: the promise of cellulosic ethanol technologies.

New technologies to resolve old problems?

At present, there is not a single cellulosic ethanol facility now in operation in the entire country. Why not? The reason is simple: the technology isn't ready for commercial operation at this time. In addition, the development of a supply chain to induce production, harvest, storage, transportation and pricing of bulky, biomass materials is non-existent. While it is possible to make ethanol from cellulosic materials such as corn stover, grass and wood and that the federal government has offered subsidies and supported substantial amounts of research, we still don't know whether or not anybody can make money by manufacturing cellulosic ethanol.

To address this deeper economic question, we've analyzed several different proposed technologies and compared them to the conventional corn grain ethanol system. With this exercise we identify the major determinants of profit in the proposed new cellulosic ethanol industry.

Focusing on the processing plant, we modeled costs of production and rates of return on invested capital for alternative methods of producing ethanol. Our goal is to provide a consistent set of estimates for the performance of the competing methods of producing ethanol in terms of net production cost before subsidies and also rate of return on invested capital after receipt of the subsidies. We seek to understand the relative competitiveness of the technologies, not report the earnings to the stockholders at their annual meeting. We are aware that there are additional second-generation biofuels, such as biobutanol and dimethyl ether that could be considered; however, we have chosen to analyze methods that have been described in detail in the literature with estimates of capital costs and operating expenses.

The methods of ethanol production analyzed here are:

1) Corn grain feedstock with purchased natural gas and electricity
2) Corn grain feedstock using corn stover for process heat
3) Corn grain feedstock using corn stover for process heat and selling electricity to the grid
4) Biochemical production using corn stover as a feedstock
5) Biochemical production using switchgrass as a feedstock

The dry-grind ethanol plant using corn and purchased natural gas and electricity for power that dries its distillers dried grains and solubles (DDGS) is by far the most common technology among Minnesota's ethanol producers.

The five ethanol production systems are compared by first constructing consistent and transparent budgets of each technology. Baseline assumptions are identified, then sensitivity analysis is performed on key variables.

Costs of production can be calculated for ethanol, the principal product, by determining the total costs and reducing them by the revenue from by-products such as DDGS, electricity sales and then dividing by the number of gallons of ethanol produced. The costs of production of ethanol at baseline conditions are shown below. Figure 1 reflects current technology costs with ethanol yields of 2.75 for corn, 57.6 gallons per dry ton for stover and 60.8 gallons per dry ton for switchgrass. We set baseline prices at $1.65 per gallon for ethanol, $114 per ton (DDGS), $6 per MMBTU (natural gas), $3.50 per bushel (corn), $89 per ton (corn stover) and $102 per ton (switchgrass).

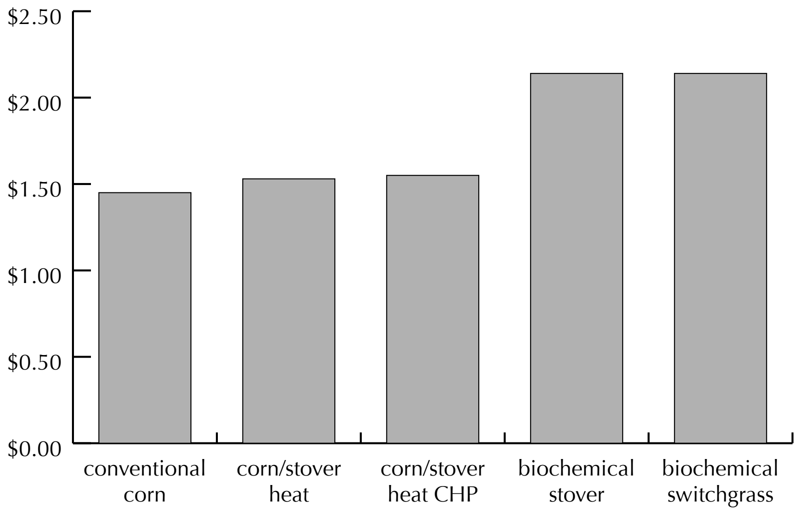


Figure 1: *Baseline net costs per gallon of ethanol reduced by by-product sales.*

Examination of the revenues and expenses of the five methods of making ethanol offers additional information about the ability of each technology to compete under various conditions. The value of the by-products can be very important with the DDGS in the case of conventional dry-grind ethanol plants as well as those using biomass as fuel for process heat. In the case of the two plants that use biochemical processes to convert the cellulose and hemi-cellulose fractions to ethanol, the value and amount of the electricity that can be sold to the grid are also important.

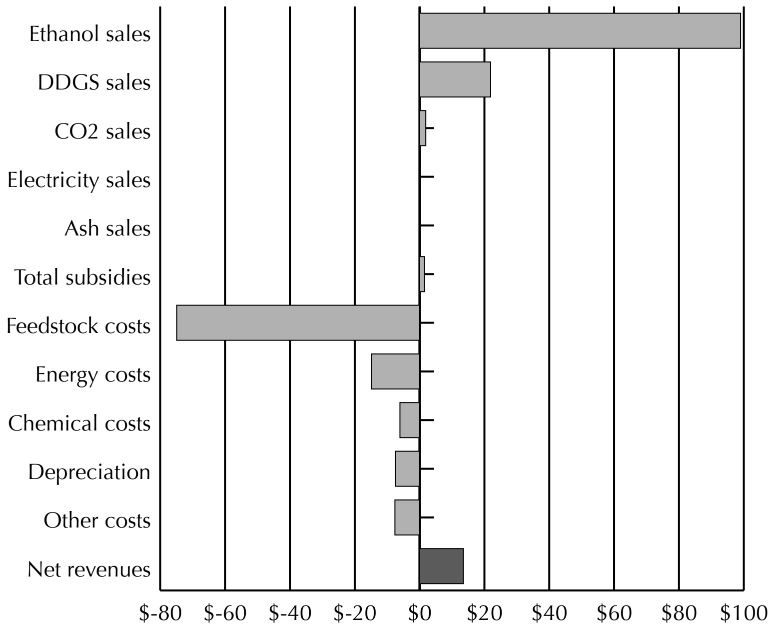
We applied capital costs for the projects based on the "nth" plant concept, which means that we are modeling installed plant costs after the contracting industry has sufficient experience to build plants with the facility shown today. We are sure that capital costs will be much higher for early plants until the engineering companies gain experience in building such plants. We expect there will be a variety of pre-treatments and other technologies that people try, so it may be some time before the design-build firms arrive at a point where the assembly and installation costs conform to the well-practiced routines we see in evidence with the conventional dry-grind ethanol plants.

While we have used yields of ethanol and by-products available in the literature, we are cautious about the ability of the biochemical corn stover and biochemical switchgrass plants to achieve performance on the more or less continuous basis that we see among the dry-grind plants. Until yields of ethanol and by-products occur predictably and on a sustained day-after-day basis with little "down time," the investment community will be wary of investments in these technologies, despite apparently favorable projected returns on the novel technologies.

Some important financial aspects of the five competing technologies are summarized in Figures 2 and 3, which show a breakdown of revenues and expenditures for the conventional corn starch plant and for the futuristic corn stover cellulosic plant. The percent of total revenue from ethanol sales ranges downward from a high of about 80% in the case of the conventional dry-grind plant. In contrast, by-product electricity sales represent only about 5% in the case of the two biochemical technologies.

Especially important is the level of subsidies received in addition to the prevailing subsidy represented by the Volumetric Ethanol Excise Tax Credit (VEETC), which is 45 cents per gallon of ethanol blended with gasoline in 2009. Our analysis reveals much higher levels of subsidy to the biochemical processes applied to corn stover and switchgrass. The two figures reveal the magnitude of the high

Figure 2: *Conventional corn using natural gas and electricity: Revenues and costs (in millions of dollars).*



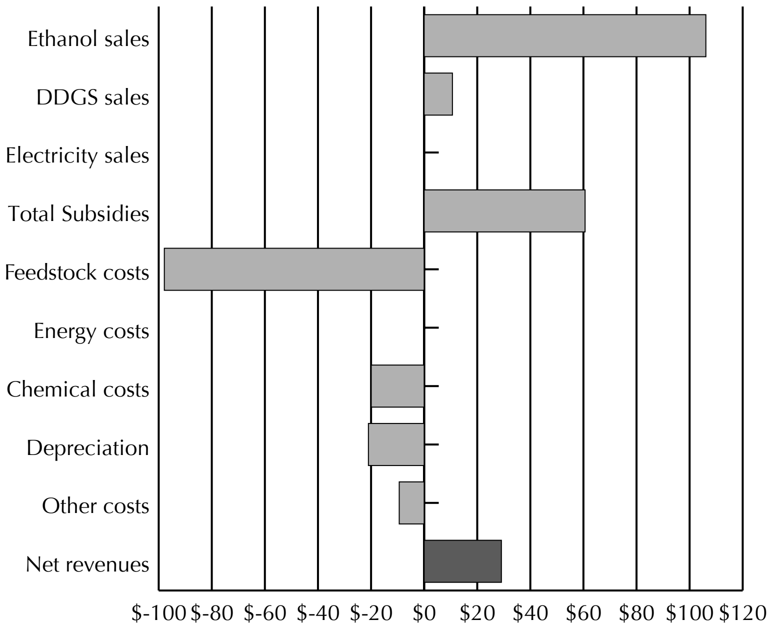


***Figure 3:** Biochemical corn stover: Revenues and costs (in millions of dollars).*

proportion of net revenues represented by subsidies for technologies that utilize cellulosic feedstocks.

Financial performance

We calculate the annual average percent return on invested capital (ROI) by dividing the first complete year's pre-tax profit by the total invested capital in each project. Figure 4 illustrates the rates of return on invested capital for the five competing methods of producing ethanol, other by-products and receipt of incentive payments under baseline conditions. Using our baseline prices and yields, conventional dry-grind ethanol plants using corn have an ROI of 12%, just above the 11.5% ROI of the dry-grind ethanol plant using corn stover for process heat.

The ROI advantage of the biochemical corn stover plant over the switchgrass plant is largely due to the cost of the feedstock assumed under baseline conditions. Corn stover is a crop residue remaining after production of the primary product, corn grain, which justifies the rental of the land. Switchgrass production requires the long-term rental of land for that dedicated energy crop and several years

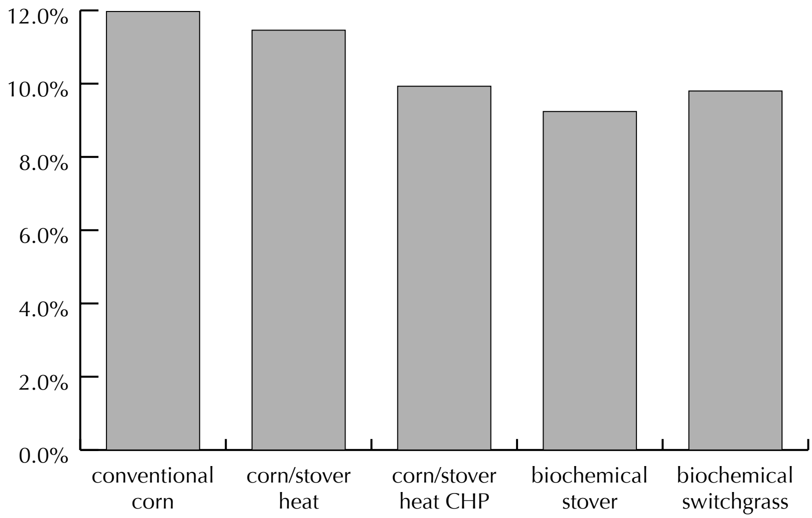


Figure 4: *Annual pre-tax rates of return on invested capital.*

of low yields during establishment. This said, the levels of the ROI are not nearly as important as the relative levels as we compare the competing technologies.

We used Monte Carlo analysis to look at the implications of varying key assumptions jointly. Briefly, the analysis calculates the resulting ROI for each feedstock and conversion technology 10,000 times in this report, each time drawing a value for each input variable from a specified range of possible values. Each calculated outcome is plotted in a probability density function to show how the outcome varies with the systematic variation of all the input variables, jointly.

In the next two figures, we show how the financial performance of each competing technology varies critically with the assumptions about future technology, market prices, and policies, specifically subsidies. In particular, the two cellulose technologies are examined under a wide range of conversion efficiencies: how much ethanol can be extracted from a given quantity of feedstock (stover or switchgrass). The range we use is bounded at the lower end by current efficiencies, which were used in the first several charts, up to and through rates that have been promised, but not so far delivered.

Figure 5 displays box and whisker plots that show the distributions of possible rates of return when all possible combinations of variables in their ranges are included. In the figure,

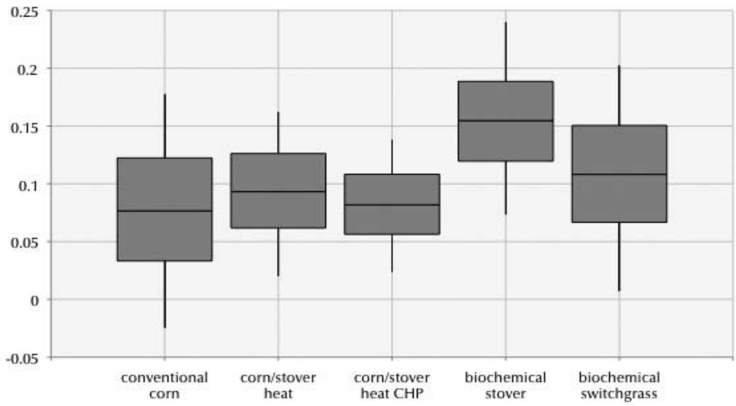


Figure 5: *Distribution of possible rates of return on invested capital.*

the bar within each box shows the median ROI for that technology. The box itself is bounded by the 25% and the 75% confidence interval values, while the tips of the vertical whiskers extend the distribution to the 5% and the 95% values.

Our comparison of rates of return on five technologies for making fuel ethanol demonstrates the importance of the substantial subsidies and incentives that have been enacted to reward cellulosic and advanced biofuels technologies when they become commercial. Our analysis of prospective cellulosic technologies is based on the concept of capital cost of the nth plant, which assumes that the substantial knowledge and installation short-cuts witnessed in today's dry-grind plants can be achieved in the biochemical plants using corn stover and switchgrass.

By-product values are important for project economics for conventional dry-grind plants or other technologies under development. However, levels of subsidies and incentives are more important when it comes to ensuring that the technologies being developed for advanced biofuels and cellulosic ethanol will produce attractive returns on invested capital. At this time uncertainty surrounds the amount of incentives or premiums that might be paid for ethanol produced with a low carbon footprint, whether enacted at the state or federal levels.

Figure 6 shows a corresponding comparison of the average rates of return for the competing technologies *without* receiving subsidies. (Recall that the current blender credit is captured in our ethanol market price: it is not considered a subsidy in the present context,

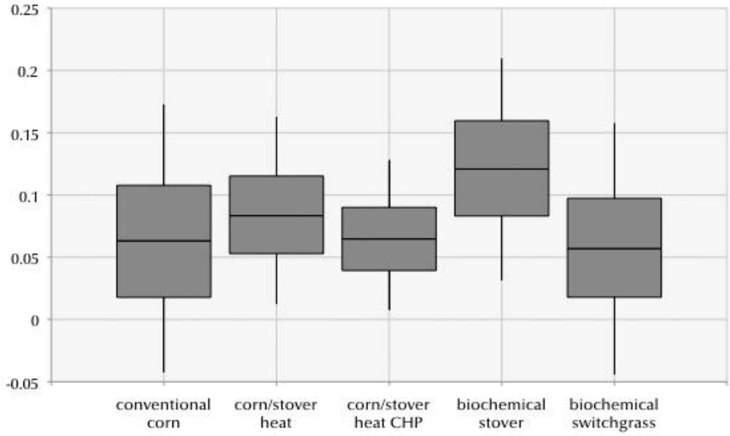


Figure 6: *Distribution of possible rates of return on invested capital with no subsidies.*

because it is not paid directly to the ethanol producer.)

In our efforts to peer ahead and gain some perspective on the success of advancing technologies that may be commercialized in the next five to ten years, our model reminds us that yield levels as well as the percentage of time that a plant is operating will be critical in efforts to overcome risks and attract private investment in the advanced biofuels and cellulosic ethanol plants.

What does all this mean for Minnesota communities?

We think there are two main lessons to be drawn from our analysis.

First of all, expectations for reducing the carbon footprint for biofuels now prevail based on complete life cycle analysis. There are high hopes that advanced biofuels and cellulosic processing methods will deliver these improvements over the prevalent corn dry-grind mills that use coal or natural gas for process heat and purchased electricity. Second, we know that the existing plants can be vastly improved in terms of their environmental performance if biomass is used as fuel to produce process heat and electricity. Corn stover and switchgrass harvest systems are being developed that may ultimately serve as "bridge technologies" to cellulosic ethanol or advanced biofuels using biochemical or thermochemical methods.

This leads us to our second conclusion. The next-generation ethanol production technologies won't just spring into being. There are a host of technical issues remaining to be resolved, and the financial performance of these systems — even with the optimistic performance assumptions we make here — leaves a lot to be desired. Without the additional boost of public policy support to reduce costs or to raise final product demand, the industry will be unlikely to move very quickly into the next generation of production technologies. We find ourselves in a situation similar to what Minnesota faced twenty years ago: a new industry that depends critically upon additional government support to move forward to provide the jobs and income — and the fuel — that this state, lacking fossil energy resources, so earnestly desires.