Commentary

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If we could create the perfect fuel, what would that be? It would be a fuel that would burn clean, improving the quality of our air. It would be a fuel that comes from many diverse, renewable resources so that we wouldn't be dependent on any one source and sources would never be depleted. It would be a fuel derived from readily available resources that have alternative uses, meaning that a raw supply infrastructure is already in place—and ideally, from which multiple products, in addition to fuel, could be made. It would be a fuel that would be miscible with current fuels, which would allow for its ready and economical use in existing vehicles and with the existing fuel-delivery infrastructure.

Time is not an ally and so our perfect fuel would be able to be produced immediately, bypassing Nobel Prize–winning science, unresolved technology issues, and uncertainty. Our fuel would be produced close to where it would be used, on a small enough scale that barriers to entry would be minimized, fuel costs to transport the product would be low, and the risk of centralized supplies or production to our national security would be lessened. It would be a fuel that would run as efficiently, or even more efficiently, than gasoline does today with little or no vehicle modifications. And finally, it would be a fuel that would readily break down in soil or water, which would dramatically reduce the environmental consequence of an accidental spill.

Does such a unique combination of attributes exist? Or is the list of desired criteria too lofty to ever achieve and thus sentences us to a future of gasoline and its negative consequences?

Astonishingly, a fuel that meets all of these criteria exists today. Ethanol from corn will provide U.S. vehicles more than 10 billion gallons of their fuel consumption in 2009. In the next several years, ethanol from a multitude of other feedstocks (such as garbage, wood chips, and unused plant material) could greatly increase our domestic renewable fuel production.

Despite the already significant contribution to our ongoing fuel needs and tremendous prospects for future contributions in only a few short years, ethanol's brightest days may be in the rearview mirror (of a car fueled by Mideast and Venezuelan oil).

How could a source that today meets so many of our objectives for a perfect fuel become so unpopular? How could the United States forgo a substantial and growing renewable fuel source for concepts that "may deliver something better, someday"?

The concept of ethanol as a renewable fuel was believed to be the ultimate vehicle fuel solution as far back as the turn of the last century with great agriculturalists like George Washington Carver, great industrialists like Henry Ford, and great inventors like Thomas Edison (Kovarik, 1998). The idea was revitalized in the 1970s during the Arab oil embargo when we feared for the security of our oil supplies (Shapouri, Duffield, and Graboski, 1995). The idea came back again in the mid-1980s when corn growers realized their net return from burning a bushel of corn was greater than from selling it to the feed market (Dorn, 2005).

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Federal Reserve Bank of St. Louis *Regional Economic Development*, 2009, *5*(1), pp. 34-41.

The idea made sense and the time was right. Energy costs were high, with corn worth more as a fuel than as a feed. Agricultural corn productivity continued to gain with no increased outlet and thus corn prices continued to languish. And standard production technologies for corn-based ethanol had been optimized such that plants could be built in an assembly-line fashion to run reproducibly and reliably.

The U.S. ethanol industry started when farmers, livestock producers, local businesses, and cooperatives pooled their own capital and invested in new-generation corn-based ethanol plants. Their objectives were clear: Increase demand for their product and create new revenue opportunities. What could not have been fully understood at the time was the positive impact of these plants on the environment and on revitalizing rural communities by creating jobs, new income, and new tax sources.

Growth of the corn-based ethanol industry was evolutionary, initially with plants averaging 20 million gallons per year (MGY) of production capacity (Hettinga et al., 2009). These early cooperatives were firmly rooted in rural agriculture. They were composed of local equity investment and agricultural debt providers who understood the cyclical nature inherent in agriculture and the low margins that could be expected from a commodity business. The majority of this growth was in the western U.S. Corn Belt where corn yields were high, local livestock production could use the animal feed coproducts, and local and regional markets could use the ethanol. Rail lines built to ship grain to California could also deliver ethanol and the animal feed resulting from ethanol production.

Modest plant construction allowed corn productivity growth to keep pace with the increased demand for corn (Korves, 2008). In other words, while farmers consistently increased their productivity (yields) in small increments each year, the small incremental growth of ethanol plants and the corn supply they required was not disruptive to corn supply and demand.

The ethanol produced in those early plants helped to meet the reformulated gasoline requirements in clean-air attainment zones and began to make its way into broader E10 (gasoline mixed with 10 percent ethanol) and E85 (gasoline mixed with 85 percent ethanol) applications. Investors were satisfied with their modest returns because of the ancillary benefits: a local alternative market for their corn, jobs for their community, and incremental expenditures for other services the plant required. The hardware store, the corn grower, the grocery store, the bank, the restaurants, the municipal government, and the local environment all benefited.

Demand for ethanol rose as states' clean-air requirements began to phase out gasoline oxygenate additives suspected of causing cancer (methyl tertiary-butyl ether [MTBE]), turning instead to ethanol. This new demand was accelerated by federal legislation that prescribed renewable fuels as a component of the gasoline blend. The 2005 Energy Policy Act (EPACT; Energy Policy Act, 2005) provided a renewable fuel standard (RFS) requirement for major petroleum blenders to blend 7.5 billion gallons per year (BGY) of renewable fuel (largely ethanol) with gasoline by 2015. More importantly, the act provided no limited liability protection for the use of MTBE. Because of the mandatory requirements to blend fuels to meet clean-air requirements, the oil industry now needed to blend fuels above the minimum level stipulated by the RFS. They rapidly exited their MTBE contracts and moved into ethanol, which briefly drove up the price of ethanol from less than $2.00 gallon in November of 2005 to $4.00 per gallon and higher prices by June 2006 (Center for Agricultural and Rural Development [CARD]).

Federal legislation created a clear marketing opportunity, and new investors from outside traditional agriculture entered the market. These new investors augmented local investors, which allowed equity to be raised more quickly. Many of these new investors also brought their knowledge and expertise from other industries and were astonished to find that the modern ethanol production technologies lacked many of the advancements commonplace in other process manufacturing facilities.

While many investors were interested in dramatically improving the process and energy efficiencies of new ethanol plants with readily available technology, they were quick to learn that established financing structures prevented funding of anything but a standard plant design template. Debt providers for new plants wanted a "sure thing" to quickly exploit the market opportunity. Improving plant technology and efficiency was not their motive for entering the market. Although higher debt loads were allowed to accommodate higher construction costs in a booming market, significant incremental operational requirements that added cost were also brought in. These requirements often included the use of external providers for corn merchandising, risk management, ethanol marketing, and coproduct marketing. Senior debt covenants limited incremental capital investment, which further restricted the adoption of significant technological improvements that experienced industrial manufacturers viewed as fundamental to the industry's future operational and financial success.

Providers of ethanol-processing equipment were also slow to push new and better technology because the new owners were positioned to buy quickly from the preestablished menu. The "old stuff" was clearly in high demand, commanding a premium, and selling in volume. Providers were having difficulty meeting demand and resources were not available to invest in the future. Reminiscent of Henry Ford's first Model T assembly lines, you could purchase and finance any process design "as long as it was black."

While it was expected that Wall Street's deep pockets would bring modern technology investments that would positively evolve the plants, this was not the case. New owners faced a dilemma: a choice of available project financing if they accepted the current state of technology, or an inability to finance their projects if they tried to improve them. Most invested, believing they would first pay off their debt and then add the diversification and enhancement capabilities core to a successful industrial production facility.

Logistical efficiencies remained despite growth of the industry because ethanol plant coproducts could now directly substitute for corn transported to cattle feed markets. These coproducts, containing all the protein, fat, and fiber of corn in a more concentrated form, cost less to transport per pound of nutrient value. West Coast markets matured, and southern and eastern ethanol and feed markets began to develop. Thus, plants began to spring up in the eastern Corn Belt with eastern-serving rail service. U.S. ethanol production capacity increased 30 percent from the end of 2005 to the end of 2006 (Renewable Fuels Association [RFA]). The large volume of corn-based ethanol now entering the distribution channel was beginning to take market share from petroleum refiners.

The nonagricultural state environmental groups became concerned that the growth of corn-based ethanol forced more land into cultivation and negatively affected our global carbon footprint. A groundswell of interest had also developed from earlier Department of Energy (DOE) work about the promise of using "wasteland" (nonproductive land) for the production of biomass crops that could "eliminate all the problems associated with corn based ethanol." Environmental groups, academic groups, DOE scientists with looming job cuts, and states with vast acres of nonproductive land coalesced to create broad-spread bipartisan support for a bill that would limit corn-based ethanol and pin future promise on alternative feedstocks and fuels.

In December 2007, the Energy Independence and Security Act (EISA) of 2007 was enacted, mandating 15 BGY of ethanol by 2015—up from the 7.5 BGY mandated in EPACT—and 36 BGY of renewable fuels by 2022 (EISA, 2007). Fifteen BGY was allowed for corn-based ethanol, and the remainder was allocated to cellulosic and other advanced biofuels (defined as any renewable feedstock except corn-based starch to ethanol). A ceiling was placed on corn-based ethanol because it was believed the need for corn for both food and fuel was causing additional land to go into agronomic production with speculated negative environmental consequences. EISA mandated that renewable fuels must demonstrate a carbon footprint 50 percent to 60 percent better than conventional gasoline and that new corn-based ethanol production facilities must demonstrate a footprint 20 percent better than gasoline.

In his February 2007 State of the Union speech, President George W. Bush proclaimed that 36 BGY of renewable fuel production, outlined in the yet to be passed Energy Bill, would allow us to eliminate three-quarters of all the oil currently imported from the Middle East…as if the 16 BGY associated with cellulosic ethanol was right around the corner.

The bill misrepresented what was possible given the current state of the science, providing the American public with a false understanding of the current potential of renewable fuels. The new law additionally served as a lightning rod to those already opposed to renewable fuels to organize and actively oppose its vision and the tangible reality of 15 BGY from corn-based ethanol.

Most astonishingly, the new bill provided the framework for the demise of the existing corn-based ethanol industry, which would effectively end the cellulosic-based industry before it was ever allowed to start. The bill neglected to offer a plan providing for the transition from an existing technology (corn-based ethanol) to the experimental technology (cellulosic ethanol) or for a certain channel for the product. Such a plan would have ensured a steady and increasing volume of renewable fuel to meet the requirements established in the RFS and a distribution system for it.

First, the vast operational efficiencies available to corn-based ethanol through available technology were bypassed for an alternative fuel that is literally still on the drawing boards. Second, the bill lacked a viable implementation plan to provide a mechanism for blending the renewable fuels mandated into the existing gasoline supply. Third, the bill created an ill-defined requirement for biofuels to achieve life-cycle greenhouse gas reductions relative to gasoline produced in 2005, including any indirect impact of the use of the land for biofuel production. Finally, the 15 billion gallons of corn ethanol allowed by the RFS immediately created a real and significant threat to the oil industry.

The EISA capped corn-based ethanol volume via a false premise that inaccurately compared it with other fuels while failing to recognize the well-known fact that corn ethanol performance could substantially improve with modest investment in available technology. In determining RFS-required volumes, the bill compared today's nascent corn-based ethanol industry with the mature sugar cane–based ethanol industry and the theoretical cellulosic ethanol industry in its risk/reward assumptions. This was one of the most frustrating aspects of the bill—it included narrowly selected measurements of the impact of renewable fuels, with limited extrapolation of their future potential, and then used these assumptions to dictate volume limits 15 years into the future.

For example, because sugar cane–based and cellulosic-based ethanol combust their by-products to fuel their plants, with the RFS measurements they are credited with minimizing fossil fuel use. In contrast, corn-based ethanol production is not recognized as having the same ability to minimize its fossil fuel use, even though this possibility exists. With this comparison, the bill wrongly relies on old corn ethanol technology performance and willfully ignores not only the new corn ethanol technology but also the current scientific and technological work that will result in commercial application during the life of the bill. And while legislators overlooked the potential of an industry already providing more than 9 BGY with outdated technology, future manufacturing concepts yet to be proved were not so burdened. As noted, sugar cane–based and cellulosic-based ethanol were again assumed to use their by-products to fuel their plants. Never were the technologies of a corn-based ethanol plant, with the adoption of technologies commercially viable today, used as the basis of comparison with either sugar cane– or cellulosic-based technologies. This yawning recognition gap in the opportunity for continued adoption of new technologies—allowing corn-based ethanol to deliver in the near term the same environmental benefits as cellulosic-based ethanol when it moves out of the laboratory and into commercial application—was completely missing from the 2007 EISA.

In addition to capping the volumes of allowable corn-based ethanol, the base number of gallons allowed was assumed "mature" and incapable of improving over time such that additional gallons could be warranted. Second, DOE funding was focused on an initiative to create a future technology. *No funding* was provided as a bridge from the current technology to that future state. This gap created the real and significant potential for the demise of the existing ethanol industry. With no future corn-based ethanol industry, no outlet above 10 BGY of production would be required, thereby eliminating the need for infrastructure development to ensure a future outlet for cellulosic ethanol technologies. This, by definition, capped our commitment to renewable fuel at a volume less than 10 percent of our gasoline usage and well below our imported volume of oil.

Why is corn ethanol's success essential to cellulosics? Although cellulosic ethanol remains a promising future fuel for reducing our dependence on gasoline as a vehicle fuel source, the time required for cellulosic ethanol to overcome significant feedstock, logistical, and production issues is not insignificant and well beyond the time allotted for production volumes established in the RFS. Additionally, the first significant volume of cellulosic ethanol is likely to come from the fiber already brought into existing corn ethanol production facilities as a part of the corn kernel. This type of cellulosic ethanol is not a new concept and, in addition to wood chips, is the nearest-term viable means of producing cellulosic ethanol. It is important to note that efforts have existed since the oil crisis of the 1970s to demonstrate its commercial viability. In 1993, the DOE National Renewable Energy Laboratory (NREL) declared its technology for converting corn cellulose ethanol ready for commercialization (NREL, 1993). Fifteen years and billions of dollars later, corn cellulose is still not ready to be produced on a commercial scale. And this technology, requiring only process-conversion technology development, will be ready long before the incremental work required to develop energy crops still in the developmental stages.

The current corn-based ethanol industry provides a means of developing the infrastructure required for cellulosic ethanol distribution. With lower costs of production and a real product to distribute, corn-based ethanol should be in a position to bear, along with the petroleum industry, the costs for infrastructure development.

The Energy Bill did not adequately address the infrastructure challenges of a 36 BGY RFS. This created a constraint for market growth and thus a supply/demand-driven market demise via margin erosion. The RFS of 36 BGY implied that 36 BGY of renewable fuels would be blended into the existing petroleum base of 140 BGY of gasoline-based transportation fuel. Gasoline infrastructure today allows for the blending of ethanol up to 10 percent in conventional vehicles, or roughly 11.6 BGY. This number excludes states that do not allow blending at 10 percent and small refiners not required to blend.

Higher use of E85 would create a significant incremental outlet for ethanol. However, while a blenders' credit of $0.51/gallon was created in EPACT and retained in EISA (reduced to $0.45/gallon in 2009) for the petroleum industry to add the infrastructure required for full incorporation of E10 and adoption of E85, there has been little to no adoption of E85 by the major oil companies.

With ethanol distribution today limited to E10, the size of the market for E10 is entirely dependent on the RFS floor (10.5 BGY in 2009) when ethanol prices (including the blenders' credit) exceed gasoline prices and is capped when gasoline prices exceed ethanol prices by the ability to blend E10: today approximately 12 to 13 BGY. Additionally, because petroleum blenders are allowed to "carry over" a portion of their blending requirements, even with an RFS floor, use of higher blend levels when ethanol's price is low allows blenders to underblend when the ethanol price is high. With 2008 use well above the RFS, petroleum blenders' 2009 mandatory blending—at an ethanol price greater than gasoline—could be 1 to 2 BG less than the 10.5 BG mandated.

As the Energy Bill was passed, incremental ethanol capacity was already under development because its lead time from construction to operation is more than two years. Thus, despite significantly reduced margins and production already above and beyond the new RFS schedule, the industry, with already committed capital, moved from 56 plants in 2000 producing 1.8 BGY to more than 180 plants in 2008 capable of producing more than 10 BGY (RFA). Thus, installed ethanol plant capacity was on line to meet the RFS mandate for 2009, 2010, and beyond. All capacity now became vulnerable with production volumes above the RFS and the lack of a "blending home." Older plants faced higher operating costs and inefficient logistics; newer plants faced higher debt loads. No plants were positioned to have the capital available or accessible to add technological innovations to improve their base assets.

Rapid industry capacity growth created speculation about the dramatic increase in the renewable fuel industry purchasing a portion of the annual U.S. corn crop, which led to corn market speculation that resulted in skyrocketing corn prices. Further, a poor European wheat harvest, increased global demand for grain, and dramatic flooding across key parts of the U.S. Corn Belt combined to create uncertainty about 2008 corn production. High and erratic corn pricing resulted, surpassed only by new highs in the price for oil and gasoline at the pump. Food companies raised prices to protect margins and were quick to cast the blame on fuel-based ethanol's demand for corn despite the small cost of grain to their total product cost (Rosenfeld, 2008).

Oil companies were further threatened by the growing volume of ethanol reducing their refining capacity needs. Food companies were threatened by an alternative demand for their feedstock that increased prices. A well-funded, well-organized campaign convinced consumers and legislators around the world that corn-based ethanol was causing starvation and food riots. An organized, fact-based information campaign was never conceived by the fragmented and poorly funded ethanol industry. Many of the anti-ethanol campaign messages are now taken as fact by legislators, the media, and other stakeholders.

Seizing another opportunity to increase the vulnerability of the industry, those opposed to corn-based ethanol began a similar campaign related to the life-cycle assessment requirements outlined in the Energy Bill. A campaign suggesting that land used for fuel instead of food production was not being appropriately penalized for its global warming impact in determining the fuel's environmental benefits. Because this criterion had never been used to determine any alternative use—say, the impact of a new subdivision, an acre grown for nonhealthy versus healthy food, or a marginal acre used for cellulosic instead of food production—new theories about how to make this determination were placed on the back of—and remain on the back of—corn-based ethanol.

The number of U.S. farm acres has largely remained flat and total tonnage of protein, fat, and fiber available for food consumption is greater than at any time in U.S. history (despite the increase in corn-based ethanol production), yet it is now believed important that an environmental penalty be assigned to corn-based ethanol in the form of the indirect land impacted—that is, the land forced into production, from the U.S. use of a portion of its corn crop for corn-based ethanol. The ongoing debate about how to determine and assign indirect land use environmental impacts in the form of its global warming impact to corn-based ethanol production—first to corn and then to cellulosic ethanol—successfully creates further uncertainty about the future of renewables, effectively stalling future investment to improve the base industry or to create incremental capacity.

Despite all this, the mid-2008 U.S. Department of Agriculture (USDA) production reports were beginning to indicate that corn yields were on track for another bumper crop. At the same time the economy began to falter, high gasoline prices led to a precipitous drop in fuel consumption and miles driven, and corn prices plummeted from a high of $7.99/bushel in late June to $5.40 in mid-August (Platts, 2008). Ethanol companies, unable to lock in margins owing to the lack of a forward market from the oil companies for ethanol, were caught with corn cost positions exceeding ethanol sales prices. A number of these companies, with significant exposure, took large write-offs, required additional capital infusions from shareholders, or declared bankruptcy. With the ethanol supply continuing to exceed mandated demand and at a price above which discretionary blending of ethanol is unattractive, ethanol margins remained razor-thin and often negative.

Stalled construction, a lack of new construction, and continued bankruptcies continued to reduce available capacity, leading to production 20 percent below available capacity (Caldwell, 2008). A lack of confidence in the future of the industry limited interest in acquisition of existing facilities or the investment required to transform these facilities into true biorefineries that could also produce food and eliminate their fossil fuel use.

Cellulosic start-ups began to announce delays in technology development, the ability to access and develop feedstock, and the ability to secure financing. The DOE publicly indicated that the near-term RFS goals for cellulosic ethanol would not be met (U.S. Energy Information Administration, 2008). In addition, overcoming the cellulosic technical hurdles to meet the RFS-mandated volume and meeting the timeline objectives outlined in the Energy Bill are proving difficult. Corn-based ethanol could most certainly help to bridge this gap, even if the industry is held to the same global warming reduction impacts possible with cellulosics, yet we have turned our back on it. Thus, while oil and gasoline imports continue, more than 2 BGY (>20%) of the existing available capacity for corn-based ethanol is idled and estimates suggest another 2 BGY reduction is possible.

All of this is happening when a simple solution exists. Instead of the DOE and the USDA funding only the speculative and basic research needs of a future industry, they could, in addition, provide grants and loan guarantees for the adoption of currently available and commercially demonstrated technologies in existing corn-based production facilities. These facilities would be those with a demonstrated ability to produce fuel and an interest in and ability to incorporate readily available technologies. These technologies would allow corn-based ethanol to deliver environmentally and economically viable ethanol with a 50 percent reduction in the carbon footprint impact—an impact that today is already 40 percent better than gasoline (Mueller and Copenhaver, 2008). This approach would bridge the time gap and technological innovation required for the introduction of cellulosic ethanol and other advanced biofuels today. This would allow time for the development of the blending infrastructure and regulations required to blend above the 10 percent level, it would ensure continued diversification of our fuel supply, and it would allow time for the development of the innovations so critical to the future of our energy independence.

REFERENCES

Bush, George W. "State of the Union Address." January 23, 2007; www.cbsnews.com/stories/2007/01/23/politics/main2391957.shtml.

Center for Agricultural and Rural Development, Iowa State University. "Historic Ethanol Margins." Ames, IA: Iowa State University; www.card.iastate.edu/research/bio/tools/hist_eth_gm.aspx.

Caldwell, Logan. "Two Year Ethanol Supply and Demand Forecast." Houston, TX: Houston Biofuels Consultants, October 2008.

Dorn, Tom. "Burning Shelled Corn as a Heating Fuel." University of Nebraska Acreage and Small Farm Insight. Lincoln, NE: University of Nebraska; December 2005; http://acreage.unl.edu/newsletter/NLS/Dec2005.htm.

"Energy Policy Act of 2005." Pub. L. 109-58, 119 Stat. 594, August 8, 2005.

"Energy Independence and Security Act of 2007." Pub. L. No. 110-140, 121, Stat. 1492, December 2007.

Hettinga, W.G.; Junginger, H.M.; Decker, S.C.; Hoogwijk, M.; McAloon, A.J. and Hicks, K.B. "Understanding the Reductions in U.S. Corn Ethanol Production Costs: An Experience Curve Approach." *Energy Policy*, January 2009, *37*, 190-203.

Korves, Ross. "The Potential Role for Corn Ethanol in Meeting the Energy Needs of the United States in 2016-2030." Chelsea, MI: ProExporter Network; October 2008; www.ilcorn.org/uploads/documents/uploader/77for%20press%20conference.pdf.

Kovarick, Bill. "Henry Ford, Charles F. Kettering and the 'Fuel of the Future.'" *Automotive History Review*, Spring 1998, *32*, pp. 7-27; www.radford.edu/~wkovarik/papers/fuel.html.

Mueller, Steffen and Copenhaver, Ken. "The Global Warming and Land Use Impact of Corn Ethanol Produced at the Illinois River Energy Center." Chicago: University of Illinois at Chicago, Energy Resources Center, July 2008; www.ilcorn.org/uploads/documents/uploader/79IRE%20GWI%20Study%20Final072908.pdf.

National Renewable Energy Laboratory. "NREL Getting Extra 'Corn Squeezins.'" NREL Technology Brief: NREL Advances in Technology at the National Renewable Energy Laboratory, NREL Report No. MK-336-5639, November 1993; www.nrel.gov/docs/gen/old/5639.pdf.

Platts. "USDA Drops Corn Price Forecast 60 Cents to $5.40/Bushel." Boston: Platts, August 15, 2008;

www.platts.com/Petrochemicals/highlights/2008/petp_ppr_081508.xml.

Renewable Fuels Association. "Statistics." www.ethanolrfa.org/industry/statistics.

Rosenfeld, Irene. "Food as Fuel; Unintended Consequences." GMA Centennial Special Issue, 2008 Forum. Washington, DC: Grocery Manufacturers Association; www.egmaforum.com/gma/2008csi/?pg=38.

Shapouri, Hosein; Duffield, James A. and Graboski, Michael S. "Estimating the Net Energy Balance of Corn Ethanol." Agricultural Economic Report Number 721, United States Department of Agriculture, July 1995; www.ethanol-gec.org/corn_eth.htm.

U.S. Energy Information Administration. "The Annual Energy Outlook 2009." Report No. DOE/EIA-0383. Washington, DC: USEIA, December 2008; www.eia.doe.gov/oiaf/aeo/overview.html.