Biomass Ethanol Production Faces Challenges

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While ethanol has been recognized as an alternative to oil, the most viable source material for it remains a controversial topic. U.S. ethanol is produced primarily from a grain, corn, which has a number of disadvantages. Cellulosic ethanol has been promoted as a replacement. We review some of the strengths and weaknesses of cellulosic biomass ethanol, and discuss its potential for becoming part of the long-run solution for supplying energy to the United States.

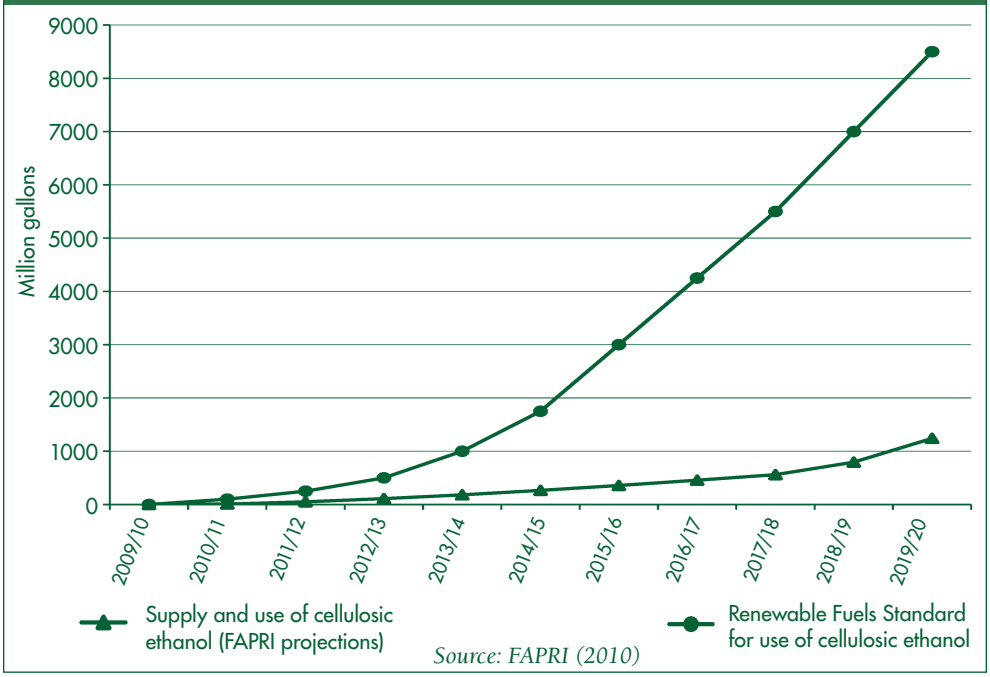
Cellulosic biomass ethanol (also called biomass ethanol) is derived from lignocellulosic or hemicellulosic matter and can be produced from various feed stocks, including agricultural waste such as rice straw, forest waste such as material created by logging, and energy crops grown specifically to produce biofuels, such as willows and other fast-growing trees and shrubs, switchgrass, and miscanthus. In general, the concept of producing a "green fuel," by transforming waste into byproducts, is attractive to many policymakers and environmentalists, and supported by some scientists. Support also exists for producing green energy using targeted crops that require fewer inputs than corn, although there is also concern that these crops compete with food crops for acreage.

In spite of the support for this energy source, there is currently no commercial-scale production of cellulosic biomass ethanol. A number of pilot projects that generate small amounts of ethanol are underway, and the first commercial-scale plant is scheduled to open in 2012. The expansion of biomass ethanol production has been much slower than projected. Policymakers' targets for levels of biomass ethanol production have not been met, leading to serious questions regarding whether or not biomass ethanol can play an important role in supplying energy to the United States.

Renewable Fuels Standards, set by the federal government in 2007 as part of the Energy Independence and Security Act, set a long-term goal of 21 billion gallons of ethanol to be produced by biomass and other non-corn starch feedstocks in 2022. Biomass ethanol production was only eight million gallons in 2010, far below the targeted 100 million gallons. Figure 1 reports specific projections by the Food and Agriculture Policy Research Institute (FAPRI) that predict this development path will continue. Given the large gap between the original targets and actual production, the Environmental Protection Agency revised its targets significantly downward, with a new 2022 target of 16 billion gallons.

One explanation for the slowness of this process is that subsidies for ethanol production have encouraged the expansion of corn-based production and discouraged innovation regarding alternative energy sources. A related explanation is that the benefits of biomass ethanol, relative to corn ethanol produced from the starch included in the grain, are not captured by ethanol producers in the absence of subsidies or by a higher buyer willingness-to-pay for ethanol with superior environmental benefits. Another is that the technology for producing biomass ethanol has faced many challenges in becoming commercially feasible. A fourth explanation

Figure 1. U.S. Cellulosic Ethanol Production and Consumption vs. Renewable Fuels Standards in 2009–2019



Source: FAPRI (2010)

Biomass ethanol production from crops such as miscanthus grass, pictured above, confront technological and economic challenges.

is that the appearance of completely new energy production technologies, such as petroleum-like hydroprocessing and direct solar-to-fuel processes, and their potential for commercial and political viability has discouraged investment in biomass technologies.

Comparison of Biomass Ethanol and Corn-based Ethanol

From the ethanol producer's perspective, there are a number of components of ethanol production costs. Feedstocks for biomass ethanol are cheaper than corn on a per-unit basis. Indeed, some of them currently have no market value. More units of biomass are required to produce a gallon of ethanol compared to corn, however, so that the feedstock cost for corn ethanol and biomass ethanol are quite similar per gallon of ethanol. The cost of converting biomass to sugar for use in ethanol is higher because the complex carbohydrate nature of biomass requires a more expensive two-stage conversion process. Overall, it is cheaper to produce ethanol from corn starch. Of course, this cost advantage varies with the price of the feedstocks. Figure 2 presents a 2010 estimate of total production costs and individual production cost components for corn ethanol and cellulosic ethanol.

The role of feedstock providers varies by the type of feedstock. For sources that are otherwise considered waste, whether or not it is supplied for ethanol production will depend on whether the net revenue from selling it is greater than the cost of disposing of it if it is not sold. Costs of marketing include transportation, and may include collection and storage.

The tradeoff is very different for potential producers of energy crops. In general, the tradeoff involves the benefits, costs, and perhaps the relative risks of producing an energy crop and growers' most profitable alternative crop. We focus here on the choice between producing an energy crop and producing corn. This choice involves a number of considerations. Biomass has two production advantages relative to corn. Corn for grain requires a substantial amount of nitrogen fertilizer per acre.

In comparison, the energy crop miscanthus requires virtually no nitrogen, and also generates sufficient biomass to produce much more ethanol per unit of production than corn grain. On the other hand, miscanthus requires more water than corn. This can reduce its relative attractiveness to growers who are dependent on irrigation to meet crops' water needs. Thus, the relative attractiveness of these crops for feedstock producers will depend in part on the costs of these inputs and the precise relationships between their input requirements under specific production conditions.

Another consideration for growers choosing whether to produce an energy crop concerns their "outside options" for marketing. There may be only one biomass ethanol producer within a grower's region. If this producer halts or reduces production, a grower may be left with an unmarketable specialized energy crop, whereas a grower who produces corn has many marketing options.

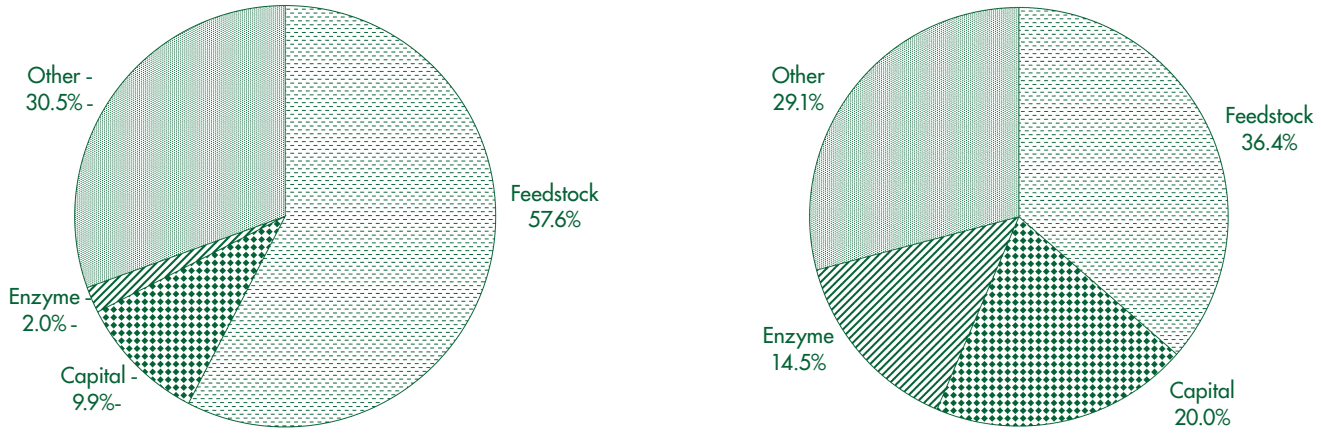
The social desirability of corn ethanol versus biomass ethanol involves many considerations. At the feedstock production level, one consideration is that biomass (miscanthus, specifically) can produce more ethanol on a per-acre basis than corn. Thus, less land is required to produce a given amount of ethanol from biomass, all else equal.

Similarly, as noted, less nitrogen fertilizer is required per acre and per unit of ethanol produced. Nitrogen fertilizer use can result in nitrate contamination of groundwater and surface water. In addition, fertilizer requires energy to produce. Even taking into account the ethanol that can be produced from the corn plant material that is a byproduct of grain production does not eliminate the advantage of miscanthus.

A significant concern regarding corn ethanol production is that it competes with other uses of corn, raising its price for uses in food directly and indirectly through raising the cost of livestock production. To the extent that energy crops compete with food crops for land, they may also raise food prices, so that there is no clear advantage for either feedstock in this regard. To the extent that energy crops can be grown on marginal land not suitable for food crop production, their effect on food prices will be lessened, increasing their social benefits relative to corn ethanol production. Using marginal lands for energy crop production may have other social costs, however, such as replacing natural habitats.

An important environmental advantage of biomass ethanol from energy crops compared to corn ethanol is that it reduces emissions of greenhouse gases over the lifecycle of the fuel, from feedstock production

Figure 2. Corn and Cellulosic Ethanol Production Costs



Source: Coyle (2010)

to final use. The advantage varies by feedstock. Switchgrass is considered a relatively attractive option.

Summarizing, the attractiveness of biomass ethanol as an alternative to corn ethanol depends on one's perspective. Feedstock growers face a complicated tradeoff; and region- and individual-specific factors will play an important role in determining which type of feedstock is more profitable to produce. From the perspective of an ethanol producer entering the market, corn ethanol is a more attractive choice economically. From society's perspective, benefits of biomass ethanol that are not captured by producers may outweigh these private benefits. However, some government policies may encourage the production of corn starch ethanol rather than biomass ethanol.

Energy Policy and Biomass Ethanol Production

Government policy has sought to encourage ethanol production in a number of ways, including providing funds for research, grants and loans to producers, income tax credits, and subsidies. Subsidies do not encourage the use of biomass for ethanol production because they do not differentiate between sources. Volume-based subsidies tend to encourage the production of ethanol from corn, which has a higher yield and lower production cost. The government has also sought to influence ethanol production through regulatory mandates, such as blending requirements for automobile fuel.

As part of the implementation of the Energy Independence and Security Act of 2007, the EPA introduced another mandate: biofuels must reduce greenhouse gas emissions over their "life cycle," including production. Specific mandates vary by source: the mandated reduction for biomass ethanol is much greater than that for corn starch-based ethanol. This mandate adds to the challenge of developing economically viable commercial-scale production of biomass ethanol.

Technology Development Challenges

From a production standpoint, biomass ethanol production is more effective when a range of biomass sources are used simultaneously. Electing not to use a mix of fuels reduces the economic viability of production. However, capturing this benefit complicates the choice of location for a commercial-scale plant and its procurement strategy.

Some supporters of corn-based ethanol argue that there are complementarities to be captured by co-locating a plant that produces ethanol from corn grain and a plant that produces ethanol from biomass. Co-location allows corn plant biomass that is a byproduct of corn grain production to be used for ethanol production. This strategy can complicate procuring a range of biofuels while capturing the environmental benefits; planting energy crops in corn production areas increases the likelihood that these crops will compete directly with food crops for acreage.

Potential Alternatives

Researchers have moved beyond improving techniques for producing cellulosic ethanol, and are investigating new technologies. These potential alternatives are primarily based on the possibility of genetically modifying crops to consume more carbon than is released when they are used as fuel. Effectively, the process is to convert carbon dioxide into carbon and oxygen. Thus, these alternatives are considered not only renewable, but "carbon-negative."

From a policymaker's perspective, encouraging further research into these technologies may have a higher expected return to society than funding additional research regarding the improvement of technologies for producing biomass ethanol.

Future Prospects for Biomass Ethanol

Technological and economic challenges confront biomass, or cellulosic,

ethanol production. To date, its production has increased much more slowly than projected. Biomass ethanol was originally seen as a more socially desirable alternative to corn ethanol. While biomass ethanol has several advantages relative to corn ethanol, it does not dominate corn ethanol in all respects. It is unclear whether investing additional resources into promoting biomass ethanol production through various policy initiatives is socially desirable, or whether it should be left entirely to private actors. To the extent that the government involves itself in developing alternatives to oil as energy sources, it may be more desirable to invest in newer technologies.

Nonetheless, biomass ethanol may have a role in the future of U.S. energy, even if it is smaller than was once imagined. One possibility could be specialized niches that generate specific advantages for a production region. In California, for example, generating ethanol from rice straw could benefit rice producers. Historically, producers burned rice straw as part of their disease and pest-management strategies. Environmental considerations have sharply curtailed this practice over the past twenty years, and no loosening of this restriction is anticipated.

While to some extent rice producers have been able to compensate for the loss of burning as an annual tool, the compensation is incomplete. For example, tadpole shrimp have increased in importance as a pest of rice grown in the Sacramento Valley. Copper sulfate is a commonly used treatment for tadpole shrimp and algae, another rice pest. There are concerns that large amounts of rice straw left in a field reduces the effectiveness of copper sulphate because it binds to the straw rather than affecting the target pest.

Developing commercial production of biomass ethanol from rice straw in the Sacramento Valley would convert rice straw from waste into a marketable byproduct for growers, and potentially aid in pest management. However, the various market considerations discussed above can limit the commercial viability of this strategy.

Biomass ethanol's potential to be a substantial contributor to U.S. energy needs is in doubt. At this time, corn ethanol dominates the U.S. market. Newer alternatives may leapfrog biomass ethanol in attractiveness for commercial production.

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For additional information, the authors recommend:

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