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Life in a Grass House

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Editor's Note: This is a guest post by Kyle.

Scouring the web with an eye toward understanding a bit more about the use of biomass-based ethanol as a replacement for gasoline, it has become apparent to me that there are a substantial number of "urban legends" emerging regarding the use of switchgrass as a feedstock for ethanol. More properly, these misconceptions are "rural legends," because at least from this former farm kid's perspective they arise from the fact that most people have very little connection to the land, and as such, are simply blowing a lot of wishful smoke about the details of a biomass-based fuel system. Hopefully the analysis below will shed a bit of light on the subject.

Ethanol, or ethyl alcohol, is produced biologically from the fermentation of various sugars from carbohydrates found in agricultural crops, and more ambitiously, from cellulosic residues from crops or wood. The process generally involves grinding the feedstock, freeing the sugar by either dissolving it (corn, sugar cane) or applying some sort of enzyme to convert the cellulose in the feedstock to sugar (see Iogen's website, for example), and then feeding that sugar to microbes (yeast) that use it for food, producing ethanol and carbon dioxide in the process. The resulting liquid must then be purified to increase the alcohol concentration. This process, of course, is not new - fermentation probably has been around since shortly after humans invented agriculture, and the use of a still to concentrate alcohol is familiar to anyone who has ever watched the Dukes of Hazard.

Currently, in the US ethanol is made from corn, which any number of studies have shown is quite marginal with regard to energy return. Paraphrasing Bob Hirsch in his most recent talk, making ethanol from corn is a process by which a certain amount of energy in the forms of natural gas and diesel fuel are used to create an equivalent amount of energy in the form of ethanol, with the primary output being money from government subsidies. However, there is substantial excitement about the potential of using biomass composed primarily of cellulose rather than starch as a feedstock for ethanol - hence the mention of switchgrass by the President in the 2006 State of the Union Address.

Switchgrass is a perennial grass native to the great plains, suitable for marginal lands because it grows well with relatively moderate inputs and can effectively protect soil against erosion. So far so good - one of the major attractions to switchgrass is that it is more environmentally friendly than corn. It contains roughly 15 million btu/dry ton, equivalent on a perfect basis to 200 gallons of ethanol per ton. However, in the distillation process some of that energy is lost, leaving the best estimates of roughly 70 gallons of ethanol per ton after distillation using a state of the art bio-reactor. Estimates for yield range as high as 15 dry tons/acre per year of switchgrass, equivalent to roughly 1000 gallons of ethanol per acre. Corn, by comparison, offers about 140 bushels per

acre, with an efficiency of 2.5 gallons ethanol/bushel, or 350 gallons per acre. This is why so many folks are beating their drums over switchgrass - in theory, it can be grown on marginal lands with ethanol yields 3 times that of corn with "minimal inputs." From this description, one gets the sense of legends in the making. Let's take a critical look at some of them.

Legend 1: Switchgrass does not require fertilizer or irrigation (America's strategic imperative: a "Manhattan Project" for energy by Lt. Col. John Amidon).

Fact: Switchgrass is a perennial grass, just like the grass in people's lawns. If you bag all your lawn clippings from your lawn, very quickly you will notice that your lawn will start to become yellow, and your "yield" (the number of times you have to mow) will decrease. This is because of the lack of fertilizer. Each time you remove biomass from an environment, you remove nutrients, and future yields will suffer. Switchgrass is exactly the same - if you harvest switchgrass for biomass, fertilizer must be applied in levels very similar to those applied if corn is the primary crop. The Auburn study showing up to 15 tons/acre of switchgrass applied 100 lbs of nitrogen per acre, and that amount is also recommended by the Iowa State University Extension Office if switchgrass is used for biomass. In addition, phosphorous and potassium (potash) must be applied in amounts consistent to the amount of biomass removed, which actually exceed that necessary for corn.

Regarding irrigation, it is true that you don't need to irrigate switchgrass, just like you never "need" to water your lawn. However, just like your lawn, switchgrass won't yield nearly as well if it doesn't have adequate moisture. In Biomass Yield Stability of Switchgrass Cultivars by Fuentes and Taliaferro, it is shown that the best-yielding switchgrass variety in Oklahoma in a location with 30 inches of precipiation/year provides about 6 tons/acre, while a location also in Oklahoma with 40 inches of precipitation/year yields 8 tons/acre. (Note that both of these were fertilized). Switchgrass yields vary strongly with precipitation - planting the dry plains, New Mexico, or Arizona with switchgrass will not yield much biomass.

Legend 2: It is estimated that 15 percent of the North American continent consists of land that is unsuitable for food farming but workable for switchgrass cultivation. If all that land was planted with switchgrass, we could replace every single gallon of gas consumed in the United States with ethanol. (Sam Jaffe, "Independence Way," The Washington Monthly (July/August 2004)).

Fact: There certainly is a significant amount of land that is non-productive for agriculture but could be planted with switchgrass. For example, in Iowa roughly 7% of the land is in what is called the Conservation Reserve Program (CRP), where the Federal government pays farmers a small amount per acre to keep that land out of production. However, there is a reason why that land is in the CRP program - it's not productive for agriculture! This could be for any number of reasons - poor soil conditions, steeply sloping fields, etc. It is not because the farmer doesn't want to plant the land - land rents for good farmland are substantially higher than the amount offered by the CRP program. Switchgrass would certainly grow on CRP land, but yields would not approach the 6-8 tons/acre on good agricultural land.

Legend 3: Switchgrass yields a certain amount now, but in the future, with selective breeding, etc., it will yield much more.

Fact: Switchgrass is a perennial, and needs to be seeded only once every decade. Is it reasonable to think that Monsanto is going to spend much research effort on seeds that they will only sell to farmers once a decade? Certainly one can select varieties of switchgrass that are more prolific (as has been done already in the Fuentes study above), but it is difficult to see that there will be much yield improvement beyond that, certainly not on timescales of a decade or so. For a wide

variety of annually varying weather conditions, soil quality, etc., it is hard to argue that switchgrass yields will exceed the 6-8 ton/acre range. We've been growing alfalfa for many years for biomass with a very high incentive to increase yields per acre, without much success. Switchgrass probably won't be much different.

Legend 4: Switchgrass is substantially cheaper as a feedstock than corn for producing ethanol.

Fact: This is the big one. How do we analyze this? Let's start with the obscure document Estimated Costs of Crop Production in Iowa - 2006. This is a useful document, as it provides insight into not only how switchgrass compares to corn in what can be argued is the best farm state in the US, but provides some insight into how things change over time due to rising fuel costs.

Costs associated with switchgrass are found on page 9 of that document, under "Annual production costs for established alfalfa or alfalfa-grass hay." Switchgrass must be cut, allowed to dry, raked, and then bailed for transport. For large, round bales of switchgrass (the cheapest method), estimated costs are $74/ton for 4 tons/acre yield, and $66/ton for 6 tons/acre yield. Presumably, that can be extended to $58/ton for 8 tons/acre yield, and so on. Note that these costs will generally be higher for smaller fields, another black mark against the use of CRP land for growing switchgrass.

On top of those costs, there will be transportation, which currently is about $0.25/ton per mile. How far will the switchgrass have to be transported? That's a bit more involved. A reasonable sized bioreactor facility would be 10,000 bbl/d, as 200 such facilities in the US would produce about 15% of the daily gasoline usage. Such a facility would use roughly 2 million tons of biomass feedstock per year, which is the output of 250,000 acres at 8 tons/acre. That is an area of roughly 400 square miles, or about 20 miles on a side. Given that rural roads don't run straight, that 20 miles is a fair figure for the average load to travel, leaving travel costs of $5/ton. So, we are talking something in the $60-70/ton range delivered to the bio-reactor. However, that is assuming 100% of the land around the bioreactor is switchgrass. If we instead only plant marginal land, the transportation distance would go up by a factor of 3 (due to the sparseness of the switchgrass fields) to $15/ton, leaving the total cost $70-80/ton. At 70 gallons of ethanol per ton of biomass, this suggests a minimum cost of $1/gallon ethanol simply to get the switchgrass to the facility. Yields less than 8 tons/acre will lead to proportionally higher costs.

How does that compare to corn? That's a bit more dicey, as corn is heavily subsidized. Wholesale corn currently costs about $1.90/bushel, while the Iowa 2006 Crop Production Cost is $3.40 per bushel (if the difference between those numbers seems incredible, remember that you, the US taxpayer, are picking up the tab). Corn is much more dense than switchgrass biomass in terms of energy per unit mass, so transportation costs are much less, certainly under $0.10/bushel. At retail, this suggests a cost of $0.80 per gallon to get the corn to the ethanol facility based upon wholesale, and $1.40/gallon based upon the Iowa Crop Production cost of $3.40/bushel.

Given that the switchgrass costs more to make into ethanol once at the bioreactor due to need for enzymes ($5-10/barrel or $0.20-$0.40/gallon plus extra energy used), there doesn't appear to be any advantage to switchgrass over corn for ethanol. One can always argue that switchgrass/byproducts could be burned for co-generation, making the distilling process less fossil fuel intensive, but a corn ethanol facility could also burn corn/byproducts for the same purpose.

As a final note, there is sensitivity to energy prices in this analysis. However, it appears to go the wrong way for switchgrass. In 2000, the Iowa Crop Cost document states that at 6 tons/acre the

cost of switchgrass was $52/ton, rising to $66/ton in 2006, an increase of 27% as the price of diesel doubled. Corn, on the other hand, cost $2.89/bushel in 2000 to produce and $3.40/bushel in 2006, an increase of 17%. This suggests that corn may become more competitive with switchgrass as time moves forward and energy costs rise, exactly the opposite interpretation most people would have anticipated. I attribute this to increased corn yields with time, which makes corn production progressively more efficient.

What's the moral in all of this? If corn ethanol is marginal on an energy returned on energy invested (EROEI) basis, it is very difficult to argue that biomass grown to make ethanol will be any better. To be blunt, if there are concentrated stocks of waste biomass in place, such as at lumber mills, then biomass ethanol probably makes sense. Otherwise, it appears to be more or less equivalent to corn based ethanol - in other words, a wash.