# Economic Analysis of Cellulosic Feedstock for Bioenergy in the Texas Rio Grande Valley

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## INTRODUCTION

Public and private funds are increasingly being allocated toward research for fuel converted from cellulosic feedstock. While some research has analyzed logistics, all of the segments required for the process, including organization, production, harvesting, transportation, or storage, are often not typically included in an integrated system. Studies have concentrated on harvesting or production, while some have made assumptions about yields, costs, and constraints that could potentially represent feasibility inaccurately. The purpose of this research is to minimize biofuels feedstocks' entire logistics cost across all components to deliver the required amount of feedstock needed for a 30-million gallon per year conversion facility, including machinery and equipment, land, water, labor, and operating costs in South Texas.

## OBJECTIVE

This research builds on an earlier study by McLaughlin (2011), where he estimated the costs of producing and supplying biofuel feedstock to a conversion facility in the middle Gulf Coast area of Texas. McLaughlin's (2011) results indicate that current and near-term logistics costs are higher than popularly proclaimed. Consideration of the Texas Gulf Coast's heterogeneity suggest there might be cost advantages farther south because of the longer growing season, added varieties of feedstock, and possibilities of available surface water for irrigation (presumed to be less expensive than the groundwater irrigation considered in McLaughlin (2011)).

In this research, McLaughlin's (2011) prior work is expanded, attempting to further identify the possible advantages to be realized in association with a more temperate geographical region, specifically the Texas Lower Rio Grande Valley (hereafter, Valley). The Valley's longer growing season (relative to the middle Gulf Coast area of Texas) is an especially important consideration, as it allows capital machinery ownership costs to be spread over more time when there are feedstocks with one or two ratoon harvests. Energy cane (i.e., a sugar cane bred to produce 10 to 20 percent more biomass (Blumenthal 2010)) also is an additional extension of McLaughlin's research incorporated into this analysis.

To conduct this economic and financial evaluation, it will be necessary to develop and apply a model for minimizing the cost of supplying a hypothetical 30-million gallon cellulosic bioenergy refinery with high energy sorghum (HES), energy cane (EC), and switchgrass (SG) in the Valley. As in McLaughlin (2011), per ton costs estimates are developed for biomass feedstock produced, harvested, transported, and stored at the conversion facility. The results will include evaluation of the land, machinery, water, and labor requirements associated with supplying the feedstock. In collaboration with Texas AgriLife Research and Texas AgriLife Extension Service soil and crop scientists, the base analysis and accompanying sensitivity scenarios are intended to evaluate the cost impact of several critical assumptions relative to biofuel feedstock production yields and other aspects of the production-, harvest-, transport-, and storage-supply chain. A major requirement is that there must be sufficient feedstock to supply the conversion facility year round. Valley-wide irrigation demand impacts associated with growing of biofuel feedstock for a conversion facility in the region are recognized. Implications for acreage of other crops competing for land as well as water prices are also considered.

## JUSTIFICATION

The U.S. Department of Energy, Department of Agriculture, and the Environmental Protection Agency are interested in increasing the role of bioenergy across the U.S. The “Vision for Bioenergy and Biobased Product in the United States” states the goal is to secure 20 percent of the market share for transportation fuels by 2030 with biofuels, which is forecasted to equal about 51 billion gasoline-equivalent gallons (U.S. Department of Energy 2006). Additionally, the Energy Independence and Security Act of 2007 mandates 36 billion gallons of renewable fuel production, including 16 billion gallons being cellulosic-based biofuels, annually in the U.S. by 2022 (H.R. 6--110th Congress 2007).

This research assumes the HES, EC, and SG grown is surface water irrigated, and will replace acres of other, currently grown irrigated field crops, such as cotton, grain sorghum, and/or corn. Valley surface water supplies are relatively constrained. Consequently, there are opportunity costs projected for land and water. That is, competition for irrigation water supplies, of substantial importance in the Valley (Stubbs et al. 2003), is addressed in this research. The Rio Grande, along the Texas-Mexico border, is the primary water source for most agricultural, municipal, and industrial users in the Valley region. Water rights were adjudicated in the late 1960s for this region, with domestic, municipal, and industrial rights having the highest allocation priority. There are 29 irrigation districts that hold irrigation water rights, the amount of which is determined by inflows, reservoir levels, and municipal allocations (Robinson, Michelsen, and Gollehon 2010; Stubbs et al. 2003). Citrus, vegetables, and sugar cane crops realize the greatest returns to Valley irrigation water, followed by cotton, corn, and grain sorghum (Texas AgriLife Extension Service 2010).

Competing demands for water resources have been increasing in the Valley because of urban growth. Irrigation water demand is variable from year to year, since agricultural economic conditions, weather conditions, and water availability all impact the demand for irrigation water. Crop prices affect the amount of irrigated acres and which crops are planted (Rio Grande Regional Water Planning Group 2010). Similarly, irrigation water supplies are affected by international agreements and weather dynamics, with drought conditions a frequent occurrence (Leidner et al. 2011).

A 2010 report by the Rio Grande Regional Water Planning Group (i.e., Region M) states the population of the Valley is expected to more than double by 2060. The demand for municipal water is projected to increase by more than 40 percent, from 288,323 acre-feet per year in 2010 to 646,006 ac-ft per year in 2060. Total water demand is also expected to increase from 1,482,932 ac-ft per year in 2010 to 1,681,920 ac-ft per year in 2060, about a 13 percent increase. Demand for irrigation water, however, is expected to decrease from 1,163,634 ac-ft per year in 2010 to 981,748 ac-ft per year in 2060.

Non-compliance of the 1944 Water Treaty between the U.S. and Mexico has created problems, with Mexico at times not delivering the amount of water required by the treaty. According to the 1944 Treaty, Mexico agreed to provide an average minimum of 350,000 ac-ft per year to the U.S. from the Rio Conchos Basin and other small tributaries that feed into the Rio Grande (Stubbs et al. 2003). Since the treaty began, however, Mexico has broken it over three cycles: 1953-1958, 1982-1987, and 1992-1997. Deficits from the first two cycles were paid back during the next cycle. For the last deficit cycle, Mexico accrued a delivery deficit of 1,400,914 ac-ft from 1992 to 2004; however, Mexico closed the 2002 - 2007 treaty accounting cycle without a deficit and in full compliance since a hurricane caused an overflow at the international reservoirs which deletes any debt (Gastélum, Valdés, and Stewart 2009). These facts on the Valley water situation serve to emphasize the importance of addressing water for irrigation as part of any bioenergy analysis conducted in this region.

## LITERATURE

The 2008 Farm Bill establishes the Biomass Crop Assistance Program (BCAP), which provides producers with payments for the collection, harvest, storage and transportation (CHST) to a biomass conversion facility. It supports establishing and producing eligible crops for the conversion to bioenergy through project areas and on contract acreage up to five years for annual and non-woody perennial crops or up to 15 years for woody perennial crops. The payments will be available at the rate of $1 for each $1 per dry ton paid by the CHST-qualified conversion facility, limited to a maximum of $45 per dry ton and limited to a two-year payment duration. Payments will be up to 75 percent of the costs of establishing an eligible perennial crop covered by the contract (H.R. 2419--110th Congress 2008). This policy is constrained by the level of appropriations approved by Congress.

A study by Fumasi, Richardson, and Outlaw (2008) focused on how bio-density, fuel prices, and type of crop produced impacts the transportation of harvesting crops in the Beaumont, Texas, area. The contract price needed to induce farmers to grow energy crops depended on the differences in yield risk, technological expertise, and capital investment. Four energy crops were evaluated: hybrid sorghum hay, hybrid sorghum green chop, high-biomass sorghum green chop, and billeted hybrid sugar cane. Comparisons to current feasible enterprises in the area were limited to cattle, rice, and pasture hay. Net returns to the producer were forecasted through Monte Carlo simulation, growing both energy and non-energy crops over a five-year period.

Billeted hybrid sugar cane was identified as the most competitive crop for the Beaumont-area producers, as it had less yield variability than the sorghum crops and is less sensitive to changes in annual input costs. However, sugar cane requires a large capital commitment for establishment and provides less flexibility in planting for the producer. This apparent conflict suggests that the producer might choose to take more yield risk to gain planting flexibility and reduce capital investments. For the biorefinery, the high-biomass sorghum was the most economical, because the required contract price and harvest, transportation, and delivered dry matter costs were all relatively low, compared to the other crop choices. The study concluded that the biorefinery would likely contract for a combination of different energy crops, since a consistent supply would be needed year round (Fumasi, Richardson, and Outlaw 2008).

Turhollow (1994) estimated biomass feedstock costs in 1989 and projected costs for 2010 to grow and supply a biorefinery with biomass in the Midwest and Southern regions of the United States using four different cropping strategies. The 2010 cost estimates were forecasted based on changing production circumstances and technology. Enterprise budgets were established for four biomass crops (hybrid poplar, sorghum, switchgrass, and energy sugar cane), as well as for several traditional agricultural crops. This approach was used to find a break-even price per ton for the biomass crops that could be comparable and competitive with traditional crops. The study determined cost of mixes of the four crops by looking at factors such as production system, variety, pre-treatment, region, and site variability. The results showed the four energy crops would need to sell at between \$48 and \$66 per dry ton in 1989 and at between \$33 and \$48 per dry ton in 2010 to be competitive with the traditional crops. The study also found that “Just In Time” (JIT) delivery, avoiding storage costs, could reduce costs by between \$7 to \$21 per dry ton.

## High Energy Sorghum (HES)

HES is a photoperiod-sensitive hybrid designed for high tonnage biomass production, combining characteristics of grain and sweet sorghums (Monk, Miller, and McBee 1984). The vegetative growth stage of 50 to 70 days for photoperiod-insensitive sorghum can be lengthened up to 170 to 180 days for photoperiod-sensitive sorghum (Rooney and Aydin 1999). Prolonging the growing period increases per acre yields and allows for a higher degree of drought tolerance, as most sorghum is more drought resistant during the vegetative growth stage (Blumenthal et al. 2007). With the longer growing season of the Valley, the main crop could potentially be supplemented by an additional one to two ratoons with irrigation (Blumenthal 2010).

### Energy Cane (EC)

EC (i.e., sugar cane yielding 10 to 20 percent more biomass than "ordinary" sugar cane) is a perennial alternative biofuel feedstock with better standing ability during a hurricane and might be productive for 10 years. This would spread establishment costs over more years and allow for more JIT delivery, reducing storage costs (Blumenthal 2010).

First generation ethanol production of sugar cane has an output-to-input ratio[1] approximately between 8:1 and 10:1. The expected increase to this ratio with cellulosic ethanol production is 40 to 50 percent (Waclowovsky et al. 2010), i.e., an output-to-input ratio between 11:1 and 15:1. Waclowovsky et al. (2010) also found the commercial average for biomass from sugar cane in studies from Australia, Colombia, and South Africa to be 39 tons dry matter per hectare per year (15.78 tons dry matter per acre per year), the commercial maximum to be 69 (27.92 tons dry matter per acre per year), the experimental maximum to be 98 (39.66 tons dry matter per acre per year), and the theoretical maximum to be 177 (71.63 tons dry matter per acre per year).

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[1] An "output-to-input ratio" refers to the ratio of energy provided by the ethanol over the energy used to produce the ethanol or an estimate of energy balance (Cohn, Bromberg, and Heywood 2005).

## Switchgrass (SG)

SG is a perennial C4 grass with high yield potential and a tolerance to water and nutrient deficits, native to North America (McLaughlin, Samson, and Bransby 1996). It is highly adaptable to many soil varieties, can tolerate diverse types of climates, and grow in areas not able to support other crop production. There are two classifications of SG: lowland and upland, both of which are considered for biofuel production (McLaughlin 2011). In a study by Wullschleger et al. (2010), the most significant predictors of biomass yield in SG were ecotype, temperature, precipitation, and nitrogen fertilization. Blumenthal (2010) estimates Valley SG yields approximate 1.61 tons per acre, or 60 percent those of El Campo (i.e., 2.69 tons per acre were identified in McLaughlin's 2011 study, assuming three tons per acre as the base maximum and accounting for seasonal reductions).

A study by Larson et al. (2010) examined the various costs of logistics methods of SG production, harvesting, storage, and transportation in Tennessee using capital budgeting. The methods were traditional large round and rectangular bale harvest and storage systems and preprocessing facilities using field-chopped material. The study also estimated changes from adjustments in operating costs, dry matter loss during storage, investment requirements, and possible savings in transportation costs between the methods.

If delivered to the biorefinery immediately after harvest, the total cost of producing SG without storage in a round bale was estimated to be \$78.27 per dry ton, \$67.70 per dry ton for a rectangular bale, and \$65.76 per dry ton for a preprocessed bale[2] (Larson et al. 2010). Costs adjusted for storage loss for up to one year were averaged, and a round bale with no protection was estimated to be \$83.02 per dry ton, \$88.80 per dry ton with a tarp and pallet, and \$99.39

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[2] A preprocessed bale is produced at a preprocessing facility, which might process the bale by cleaning, separating and sorting, chopping, grinding, mixing and blending, controlling moisture, densification, and packaging the SG before it is stored or transported to the biorefinery facility (Larson et al. 2010).

with a tarp and gravel. The rectangular bale averages were estimated at $86.22 per dry ton when using a tarp and pallet and $92.48 per dry ton with tarp and gravel. The preprocessed bales were assumed to not have storage loss; however, the average weighted cost by the volume delivered to the biorefinery each month over a year was $59.41 per dry ton.

Total capital investment costs, including harvest equipment, vehicles, and the costs for the preprocessing facility in the case of preprocessed bales, for a 25-million gallon biofuel facility was estimated to be $31,955,000 for round bales, $20,780,500 for rectangular bales, and $19,635,150 for preprocessed bales. The baler machinery and tractors were shown to be significant investment costs, which caused the traditional bale methods to have the higher capital investment costs. Larson et al.'s (2010) results suggest the preprocessing facility system would perform better than conventional hay methods in terms of delivered cost to the biorefinery, and traditional hay systems might not be the most cost-effective.

In the baseline results of McLaughlin's (2011) research, the total average annual cost to supply the 30-million gallon conversion facility with HES and SG in El Campo, Texas, was estimated at $53.75 million. The total annual amount of HES produced was 313,255 dry tons on 36,950 acres, while 100,000 dry tons of SG were produced on 37,213 acres. Therefore, 413,255 dry tons of feedstock were produced on 74,163 acres to supply feedstock to the conversion facility for one year. The average HES yield was calculated to be 8.48 dry tons per acre, (assuming a base maximum yield of 12 dry tons per acre), while the SG yield was 2.69 dry tons per acre (assuming a base maximum yield of three dry tons per acre) (McLaughlin 2011). The total delivered feedstock costs was $1.79 per gallon of fuel produced, assuming a fuel conversion rate of 75 gallons per dry ton (Avant 2009) and using the 30-million gallon conversion facility size.

## METHODOLOGY

A linear programming model patterned after the McLaughlin (2011) research is planned for the Valley. The model will incorporate both capital budgeting and related annuity equivalents and enterprise budgeting in coordination with considering the effects of timely field operations. Capital budgeting evaluates net cash flows of an investment over their economic life (Penson and Lins 1980). Life-cycle annuity equivalents are based on Rister et al. (2009) and are used with Net Present Value analysis. Enterprise budgeting concepts facilitate comparisons of costs and returns of alternative crop activities and allow for evaluating technology, resources, and management practices (Kay et al. 2003).

The multiple-period, 12-month model proposed for this research facilitates evaluations of different alternatives for feedstock supplies and timing of related production practices and harvesting, in addition to transportation from field to storage and storage activities. The model allows for specifications of time periods available when field operations (including harvesting, hauling, and storage) can be performed, as well as identification of the periodic hours available for operations. These model features, combined with consideration of the amounts of machinery and labor required, in conjunction with extensive sensitivity analyses, are directed to identify the most important factors impacting costs to deliver biomass feedstock to a conversion facility for the study area.

Information to modify and expand the model first developed in McLaughlin (2011), including coefficients, is based on Delphi interviews with Valley producers and other professionals. However, because McLaughlin’s model is built in Microsoft Excel, there are limitations to how much it can be expanded. The model is currently reaching the limit of the number of columns available in Excel 2010. Adding more activities means existing portions of the model will need to be condensed. This might be accomplished by reducing the possible field operations available or changing from biweekly field operations to monthly field operations.

Another possible solution is to transpose the linear programming model, using the Dual of the model, which would transform the current columns into rows and the current rows into columns. This would be useful because Excel has substantially more rows than columns available, with no perceptions of model size being an issue under this approach[3]. To interpret the results with this method, shadow prices would have to be used instead of results from the objective function to reflect activity levels.

Enterprise budgets for the HES, EC, and SG crops will be developed to ascertain current expected returns to land and water in each study area irrigation district for alternative crops, especially cotton, milo, corn, and soybeans. Also considered are sugar cane, vegetables, and citrus, to identify and confirm their dominant positions.

### Valley Irrigation District Manager Survey

An important preliminary phase of this research involves a survey of the managers of the five to ten Valley Irrigation Districts (IDs) most likely to have adequate land and water for irrigation of biofuel feedstock. This questionnaire is intended to determine the amount of water each district has available for irrigation annually, estimates of current planted acres by crop, water use per acre by crop within the irrigation district, and water delivery prices. In addition, information relative to annual variability of district water availability will be solicited.

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[3] Certainly another approach to developing the linear programming model envisioned for this research is to use GAMS (Brooke, Kendrick, and Meeraus 1988). However, the preference at this time is to remain in the Excel environment, used in Sorghasauras© by McLaughlin (2011), to facilitate data entry and output reporting.

## Revisions Required in McLaughlin’s (2011) Model

To move the application of McLaughlin's (2011) model to the Valley, numerous changes are required:

1) As opposed to the specification in McLaughlin (2011) with only one form of HES production (i.e., one crop annually), three alternative forms are specified for the Valley: irrigated with one ratoon, irrigated with two ratoons, and dryland (with one annual crop).
    a) This will require more columns in Excel, which is a major limitation.
    b) Planting and harvest dates, yield curves, and amount and timing of irrigation for each HES form in the Valley will be developed in conjunctive with research results and with experts.
2) EC is to be included as a cropping possibility.
    a) EC could potentially have a main crop plus either one or two ratoons.
    b) Adding EC will also require additional columns in the model.
    c) Planting and harvest dates, yield curves, and amount and timing of irrigation will be developed in conjunctive with research results and with experts.
3) A possible consideration to be incorporated into the model is that some machinery and/or equipment could be leased from a nearby sugar mill.
    a) This might not require much change to the model if it is considered the only available leasing option for each machinery item.
    b) The specifics of such possibilities will be identified in conjunction with management of the Valley’s Santa Rosa sugar mill.
4) For irrigation, selected water districts in the Valley will establish land availability, water costs, and availability of water.

a) Land use for competing crops, associated net returns, and amount of water used for current crops, (i.e., the defenders) represent current opportunities, thereby being the opportunity costs with which biofuel feedstock crops (i.e., the challengers) must compete.

b) For each ID, the same enterprise budgets are assumed for current crop enterprises, but ID-specific water delivery cost schedules will be used.

5) Custom farming is a possibility to be considered, assuming land, water, and machinery operations (except harvest and logistics) are done contractually by farmers, similar to Valley sugar cane production and harvesting (Rister et al. 1999).

a) Similar to handling of SG establishment costs in McLaughlin (2011), custom farm activities need to be defined. In addition, those endogenous corporate farming activities which will be substituted by custom farming activities need to be identified. Subsequently, model relationships allowing for the choice of the endogenous corporate activities or custom farming activities will be incorporated.

b) A set of custom harvest activities will be defined that mirrors the operations of the corporate farm, with the constraint of available time. Yield relationships for planting and harvesting and custom farming costs on a per acre basis will be identified.

Specific supplementary data needs include:

1) Quantify IDs lowest opportunity costs for water and how restricting proportions of biofuels feedstock crop acreages to specific IDs influences costs.

2) Other local data requirements include labor availability, trafficable days, and day length differences with respect to Valley conditions versus the Middle Gulf Coast region evaluated in McLaughlin (2011).

## Planned Analyses

A baseline scenario will first be defined. Sensitivity analyses will then be performed to gain insight into the most essential factors effecting costs. The following list of sensitivity scenarios, being conducted by McLaughlin (2011), will be considered:

- Above-average HES yield, irrigation, with and without part-time labor during harvest;
- Average HES yield and no irrigation;
- Below-average HES yield and no irrigation;
- Trafficable days at 50 percent;
- Trafficable days at 90 percent;
- Operating costs –/+ 15 percent;
- Capital costs –/+ 15 percent;
- Discount rate – 1 percent;
- "Better Case" (Average HES yield, no irrigation, capital costs – 15 percent, part-time labor available); and
- "Best Case" (Above-average HES yield, no irrigation, capital costs – 15 percent, part-time labor available).

Relative to the hypotheses of this thesis, these results will be used to subjectively evaluate compared to McLaughlin (2011). This will allow for validation, to confirm the model is giving appropriate results (i.e., results are occurring with both the expected sign and magnitude or can be explained).

Additional analyses will also be performed, to determine effects and also validate the changes incorporated in the Valley's model, relative to that used by McLaughlin (2011). These analyses will include:

- Allowing only HES;
- Allowing only EC;
- Above- and below-average yields for EC;
- Irrigation water changes (make limiting factor and/or allow to be unlimited);
- Not allowing leasing of machinery from the sugar mill;
- Not allowing custom farming operations; and
- Only allowing one ratoon for each crop.

### Economic Impact Analysis

Economic impacts due to the addition of the bioenergy industry in the Valley are estimated using the IMPLAN model, which generates impacts associated with changes in output of economic sectors. The IMPLAN model can be applied to develop estimates of economic impact in employment and/or economic activity for a region, state, or the nation (Minnesota ImPLAN Group, Inc. 2004). The multipliers from IMPLAN provide estimates of total value of goods and services (production) by industry, measures of change in value added resulting from economic activity, and the change in number of jobs (Seawright 2009). The multipliers can give further information to compare to McLaughlin's (2011) results and also give details on economic changes that could potentially be seen in the Valley if producers were to start growing cellulosic feedstock.

## SUMMARY

The model developed for this research will minimize the cost to supply a 30-million gallon cellulosic bioenergy refinery with HES, EC, and SG in the Valley, based on previous work done by McLaughlin (2011) in the El Campo, Texas, area. Production, harvesting, transportation, and storage costs will be estimated, and will include evaluations of the land, machinery, water, and labor requirements necessary to continually supply the biofuel facility year-round with feedstock. The important considerations for this research in the Valley include irrigation water rights, opportunity costs for competing crops, the addition of EC, longer growing season length, and the possibility for ratooning with HES and EC.

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