# Final Report

## Xcel Renewable Development Fund Project (RD-56)

# Generating Electricity with Biomass Fuels at Ethanol Plants

## Chapter/Task 1 – Applicable Biomass Co-Product Streams

**This chapter provides an overview of potential biomass co-product streams (DDGS, syrup, DWG) available at ethanol plants or near plants (corn stover). It was primarily prepared by project participants at RMT Inc.**

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# RD56: Generating Electricity With Biomass Fuels at Ethanol Plants Report for Task 1, "Applicable Biomass Co-Product Streams"

## Background of the Task

A wide variety of biomass fuels are potentially available for use in providing energy for the production of fuel-grade ethanol. These potential biomass fuels include wood (virgin chips, waste wood such as harvesting slash and wood from storm damage, wood processing residues such as sawdust and shavings, and such miscellaneous items as pallets and cribbage), distressed grain (excess seed, moldy or wet, contaminated, etc.), agricultural processing residues (hulls, husks, pits, rejects, etc.), and so-called "energy crops" (switch grass, etc.). Also generally classified as biomass fuels are such materials as waste paper and refuse-derived fuel (RDF).

This project focuses on a type of biomass fuel specifically generated at dry grind fuel ethanol plants, namely, the co-products of the ethanol production process itself, and the stover derived from growing the corn that is the dominant feed material for dry grind ethanol plants. These co-products, described in detail below, offer several benefits as fuel for dry grind ethanol plants. The co-products are already located at the ethanol plants, eliminating transportation costs. If the selling price of the co-products is depressed, the plants can potentially derive greater value by extracting the energy content of the co-products rather than selling the co-products themselves. The co-products leaving the process have a high moisture content (about 65%-70%) and a limited shelf life (from days to a few weeks with additives). Drying allows easier handling and a much longer shelf life (months or more), but at a high energy cost. Use of the co-products as fuel may not require as much drying, or may allow more efficient drying. One of the co-products (syrup) is becoming increasingly problematic, and may be most efficiently and effectively dealt with through its use as fuel. Recently, the literature has contained information concerning a new system to efficiently decrease the moisture content of the syrup to 40%-50%, or less. According to the literature, such systems are currently in trials in ethanol plants, and other systems are on order by other ethanol plants. Information regarding where the trial systems are located, and specific engineering or operational information about the systems, have not been made available by the manufacturers. This report therefore does not include further descriptions of such systems, or projections of such systems' effectiveness or utility. However, if such systems are effective and cost effective in reducing the moisture content of the syrup to less than 50 percent, mathematical modeling for this project indicates that stable, self-sustaining combustion of the syrup may be feasible.

The primary products of the fermentation process used to produce fuel ethanol are anhydrous ethanol, carbon dioxide, and solid and soluble stillage. Solid and soluble stillage consists primarily of yeast cells and of the nonstarch portions of the feed stock, as well as whatever starch was not fermented. The nutritional composition of the nonstarch feed stock residues include protein, fat, and fiber.

The solid and soluble residues begin as "whole stillage," which is the material remaining after the ethanol is removed from the mash in distillation columns. The whole stillage is processed in centrifuges to separate a solids-containing portion (distillers wet grains, or DWG) and a solubles-containing portion ("thin stillage"). The DWG can be dried to produce distillers dried grains, or DDG. The thin stillage is further processed through distillation to remove additional water, resulting in a viscous stream referred to as "syrup." The syrup may be sold separately as an animal feed additive, or it may be combined with the solids-containing stream from the centrifuges, a mixture referred to as distillers wet grains with syrup (also sometimes referred to as "solubles"), or DWGS (often also called DWG). The DWGS can be dried, to produce a material referred to as distillers dried grains with syrup, or DDGS.

DDGS has operational and marketing benefits over DWGS, including a much longer shelf life, reduced odor, easier handling, and lower transportation costs. However, the drying of the DWGS is a major user of energy, usually in the form of natural gas, for an fuel ethanol plant. Owing to the high proportion of water in the syrup (typically about 70%) and the syrup's physical characteristics, the drying of the syrup is particularly energy intensive. The DWGS drying operation is also a major source of raw air emissions from fuel ethanol plants.

The distillers grains and solubles have a substantial energy content; indeed, the recoverable energy is projected to be sufficient enough to place substantial electricity from the biomass combustion onto the external electricity grid. Residual steam following electricity generation can replace natural gas in distillers grain drying (depending on equipment), increasing the attractiveness of biomass co-product combustion.

A major potential biomass energy source associated with corn production is corn stover, which is composed of the stalks, leaves, cobs, and husks of the corn plant after the kernels of corn are removed. Corn stover is potentially low cost and is generally generated in the same geographic area and by the same growers as the corn raw material for the ethanol plants. The physical and chemical characteristics of the corn stover may make it a feasible adjunct to the current ethanol plant co-products streams. Corn stover could also represent an economic value-added component for both the farmer and the ethanol plant. However, corn stover has significant challenges in industrial-scale energy applications. It is a seasonal, opportunistic material, and substantial investment would be needed to process and store it for availability as a year-round fuel. The bulk density of corn stover is low, making collection, transportation, storage, and processing costly. The moisture content of typical corn stover is highly variable, and moist corn stover rapidly degrades. Corn stover, especially if collected post-harvest off the ground, may contain considerable contamination, both physical (dirt, rocks, and debris) and biological (both micro- and macro-organisms). Because new technologies are being developed that may overcome some of these drawbacks, this project will include corn stover in the overall evaluation of applicable biomass fuels.

## Evaluation of Potential Feed Streams to be Sampled

This project evaluated the fuel characteristics of various feed streams that could potentially be used for combustion. These potential feed streams are listed in Table CS1. These feed streams comprise the components of the ethanol plant co-product streams and their combinations, as well as their combinations with corn stover. These potential feed streams are potentially present in all dry grind fuel ethanol plants, regardless of the plant designer or builder. Operational factors may cause variation in potential feed streams for any particular plant. For example, a plant that burns syrup to produce process steam will therefore produce no DDGS. Plants that do not have dryers will likewise not produce DDGS. However, all feed streams listed in Table CS1 were evaluated because of their wide general applicability and because any given plant may change its process or production needs over time.

**Table CS1**
**Potential Combustion Feed Streams**

| STREAM # | DESCRIPTION |
|---|---|
| 1 | Whole stillage |
| 2 | Distillers wet grains without syrup |
| 3 | Distillers wet grains with syrup |
| 4 | Thin stillage |
| 5 | Syrup |
| 6 | Distillers dried grains without syrup |
| 7 | Distillers dried grains with thin stillage |
| 8 | Distillers dried grains with syrup |
| 9 | Corn stover |
| 10 | Whole stillage with corn stover |
| 11 | Distillers wet grains without syrup, with corn stover |
| 12 | Distillers wet grains with syrup, with corn stover |
| 13 | Thin stillage, with corn stover |
| 14 | Syrup, with corn stover |
| 15 | Distillers dried grains without syrup, with corn stover |
| 16 | Distillers dried grains with thin stillage, with corn stover |
| 17 | Distillers dried grains with syrup, with corn stover |

## Evaluation of Potential Feed Streams for Analytical Testing

The potential combustion feed streams listed in Table CS1 were evaluated to develop a sampling and analytical protocol for execution of feed stream analyses. The protocol was designed to yield the maximum useful data for the lowest cost, thus making efficient use of project funds.

It is not necessary to analyze every potential feed stream for every parameter. Some of the potential feed streams are composed of combinations of component streams that will be analyzed. For example, distillers wet grains with syrup is simply a combination of the syrup with the distillers wet grains without syrup; there is no further processing, and so there is no chemical change in either component. Likewise, all combinations with corn stover can be evaluated by combining the data from corn stover with the data from the other component feed stream, because the combination is not subject to processing that would significantly affect the chemical analyses. On the other hand, when distillers wet grains with syrup are dried to produce DDGS, the high temperature of the drier will produce chemical changes, and the physical action of the drier will cause the loss of some fine particulate, which may in turn change both the physical characteristics and the chemical balance of the final product.

Since the project was proposed, additional relevant data have become available from the literature, from producer plant Internet sites, and from technical and industry conferences. These data will be evaluated for relevance and for general quality, and the data deemed suitable will be used as much as possible to avoid duplication of effort and to allow project funds to be expended on other project pursuits for which such data are not readily available.

Table CS2 presents the evaluation of potential feed streams for analytical testing, including comments relative to potential use as biomass fuel, based on the project team's applicable predictive experience in the ethanol and other industries.

**Table CS2**
**Evaluation of Potential Feed Streams for Analytical Testing**

| STREAM # | DESCRIPTION | EVALUATION FOR TESTING | TEST? |
|---|---|---|---|
| 1 | Whole stillage | The water content is judged to be too high for practical burning. Whole stillage is composed of a solids portion that will become DWG and a solubles portion that will become syrup, each through a physical separation. Both DWG and syrup will be analyzed. | No |
| 2 | DWG without syrup | The moisture content is judged to be too high for practical self-supporting combustion. However, removal of some of the moisture, or supplementation with other fuel, should allow for such combustion, so the material will be analyzed. | Yes |

## Table CS2 (continued)
## Evaluation of Potential Feed Streams for Analytical Testing

| STREAM # | DESCRIPTION | EVALUATION FOR TESTING | TEST? |
|---|---|---|---|
| 3 | DWG with syrup | The DWG and the syrup will be analyzed separately. | No |
| 4 | Thin stillage | The water content is judged to be too high for practical burning. The thin stillage is concentrated into syrup, and the syrup will be analyzed. | No |
| 5 | Syrup | Although the moisture content of the syrup is judged to be too high for practical self-supporting combustion, syrup is reportedly being successfully burned for energy at one plant, with the use of auxiliary fuel. Production refinements in the industry may increase the quantity of syrup produced while changing the chemical makeup of the syrup. The resultant change in the economic value of the syrup is uncertain. It is likely that more syrup will be produced than the plants desire, so elimination by energy recovery may become an increasingly attractive option. New systems to significantly reduce the moisture content of the syrup will greatly enhance the syrup's potential use as fuel, but are not expected to change the chemical makeup or the moisture-free heat potential of the syrup. | Yes |
| 6 | DDG without syrup | When dried to DDG, chemical changes may take place in the DWG, including minor loss of dry-basis heat value. Comparison of DWG with DDG will allow for an evaluation of the effects of various degrees of drying the DWG prior to combustion. | Yes |
| 7 | DDG with thin stillage | The water content of the thin stillage will likely more than negate any additional combustion benefits to be gained through drying the DWG. | No |
| 8 | DDG with (undried) syrup | The DDG and the syrup will be analyzed separately. | No |
| 9 | DDG with (dried) syrup (DDGS) | Depending on the drying technology and conditions, drying the DWG and syrup may result in chemical changes, including minor loss of dry-basis heat value. Nevertheless, DDGS is expected to have the highest heat value of any material in this project, and is produced by most plants. | Yes |
| 10 | Corn stover | Data generated in this project will supplement existing literature data. | Yes |
| 11 | Whole stillage with corn stover | The high water content of the whole stillage is judged to make burning impractical. | No |

**Table CS2 (continued)**
**Evaluation of Potential Feed Streams for Analytical Testing**

| STREAM # | DESCRIPTION | EVALUATION FOR TESTING | TEST? |
|---|---|---|---|
| 12 | DWG without syrup, with corn stover | Data from DWG and corn stover can be combined to allow for an evaluation of this mixture. | No |
| 13 | DWG with syrup, with corn stover | Data from the DWG, syrup, and stover can be combined to allow for an evaluation of this mixture. | No |
| 14 | Thin stillage, with corn stover | The high water content of the thin stillage is judged to make burning impractical. Data are available for corn stover. | No |
| 15 | Syrup, with corn stover | Data from syrup and corn stover can be combined to allow for an evaluation of this mixture. | No |
| 16 | DDG without syrup, with corn stover | Data from DDG and corn stover can be combined to allow for an evaluation of this mixture. | No |
| 17 | DDG with thin stillage, with corn stover | The high water content of the thin stillage is judged to make burning impractical at any reasonable percent of thin stillage. Data are available for DDG and corn stover. | No |
| 18 | DDG with syrup, with corn stover | Data from the separate components can be combined to allow for an evaluation of this mixture. | No |
| 19 | DDGS and corn stover | Data from the separate components can be combined to allow for an evaluation of this mixture. | No |

## Potential Effects of Changes in Raw Material Preprocessing

The dry grind fuel ethanol industry has been in a state of technological change since its inception. Changes have focused on reducing environmental impacts, improving efficiency, lowering costs, enhancing production flexibility, and creating more value-added products and co-products. Raw material preprocessing through fractionation prior to liquefaction, and recovery of certain components following distillation, have gained greater interest. New processes are in development, and have in some cases been installed, to achieve fractionation or biorefining. The primary separated co-products of the preprocessing fractionation are the germ/oil and the fiber (bran), while the primary separated post-fermentation co-product is oil.

The potential effects of germ/oil and fiber removal on the selected co-products feed streams are expected to have both positive and negative impacts on combustion. On the positive side, the removal of fiber could make processing of the feed streams for injection via nozzles into conventional (nonfluidized) combustion units easier, could improve flowability, and could lower the amount of sulfur in the feed. On the negative side, the high heat content of the germ, because of its oil component, is unavailable for combustion, and the fiber, which may aid in dewatering the whole stillage, is also unavailable for combustion. Additional testing will be necessary to quantify these potentials, and the variability inherent in the different fractionation technologies should also be considered. If suitable samples are available in time, limited analyses and data evaluation may be incorporated into the project results.

## Partner Ethanol Plants

Table CS3 lists the partner ethanol plants from which samples were obtained. To protect the confidentiality of the plants, the individual samples are not identified by plant name in this report. The analyses performed, and the analytical results, are given in the Feed Stream Analysis section of this report.

**Table CS3**
**Partner Ethanol Plants**

| PLANT NAME | PLANT LOCATION |
|---|---|
| Ace Ethanol, L.L.C. | Stanley, Wisconsin |
| Agri-Energy, L.L.C. | Luverne, Minnesota |
| Badger State Ethanol, L.L.C. | Monroe, Wisconsin |
| Chippewa Valley Ethanol Company | Benson, Minnesota |
| Corn Plus, L.L.C. | Winnebago, Minnesota |

A sample of corn stover was obtained from the University of Minnesota Department of Biosystems and Agricultural Engineering.

Analytical results are discussed in the "Analysis of Biomass Co-Product Streams" section of this report.