

Project Title: Biomass Electricity Generation at Ethanol Plants - Achieving Maximum Impact

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**Congressional District: Minnesota fifth (UofM Sponsored Projects Administration)
Minnesota fourth (UofM Bioproducts and Biosystems Engineering)**

Executive Summary

- Updated project web site www.biomassCHPethanol.umn.edu to reflect the new project
- Developed a preliminary model of biomass integrated gasification combined cycle (BIGCC) power production in Aspen Plus.
- Defined four potential business models (organizations) for electricity production at ethanol plants. They include: 1) public agencies; 2) municipal, REA Coops, and other publicly-owned utilities; 3) investor-owned utilities; and 4) private developers.
- Developed a preliminary model for a logistics system that would deliver corn stover to an electricity generation facility at an ethanol plant on a year around basis.
- Developed sign contracts with our subcontractors, LLS Resources, LLC and AMEC E&C Services Inc.
- Communicated about project activities; carried out project management, accounting, and reporting functions.

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Technical Progress

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Summary of Tasks Listed under Milestone 1

1A Integrated gasification combined cycle analysis

- Begin modeling Combined Cycle System performance
- Begin determination of drying requirements for syrup-stover configuration

A preliminary model for biomass integrated gasification combine cycle (BIGCC) power production has been developed. Some of this work was done following the completion of the previous Xcel RDF project (RD-56) and the beginning of the current project to take advantage of the expertise of Matt De Kam. Matt completed his M.S. thesis and left the University in August 2008. The modeling work is now being continued by a new student, Huixiao Zheng, and a new research associate, Nalladurai Kaliyan. A summary of the model and a few preliminary results are provided below.

A simplified diagram of the BIGCC power generation system is shown in Figure 1. In this arrangement biomass fuel is gasified and combusted in a twin fluidized bed process to produce synthesis gas. The synthesis gas passes through a gas cooler which generates some process steam. The gas is then cleaned, compressed and combusted in a gas turbine. The hot combustion products from the gas turbine and the fluidized bed combustor are used to provide heat to the steam generator. The assumptions made for steam generation are the same as in all previous cases.

Superheated steam at 482° C (900° F) and 6,300 kPa (900 psig) exits the steam generator and is piped to a backpressure steam turbine losing 5° C (9° F) along the way. The turbine specifications are the same as those used in the CHP cases. After desuperheating, process steam is then supplied at 446 kPa (50 psig) to the ethanol process, the ethanol co-product dryer, and the gasifier fuel dryer. The gasifier fuel is a mixture of syrup and corn cobs. Because the gasification process requires fuel moisture contents less than about 20%, the syrup (approximately 67% moisture) and corn cobs (approximately 13% moisture) are mixed and then dried before gasification.

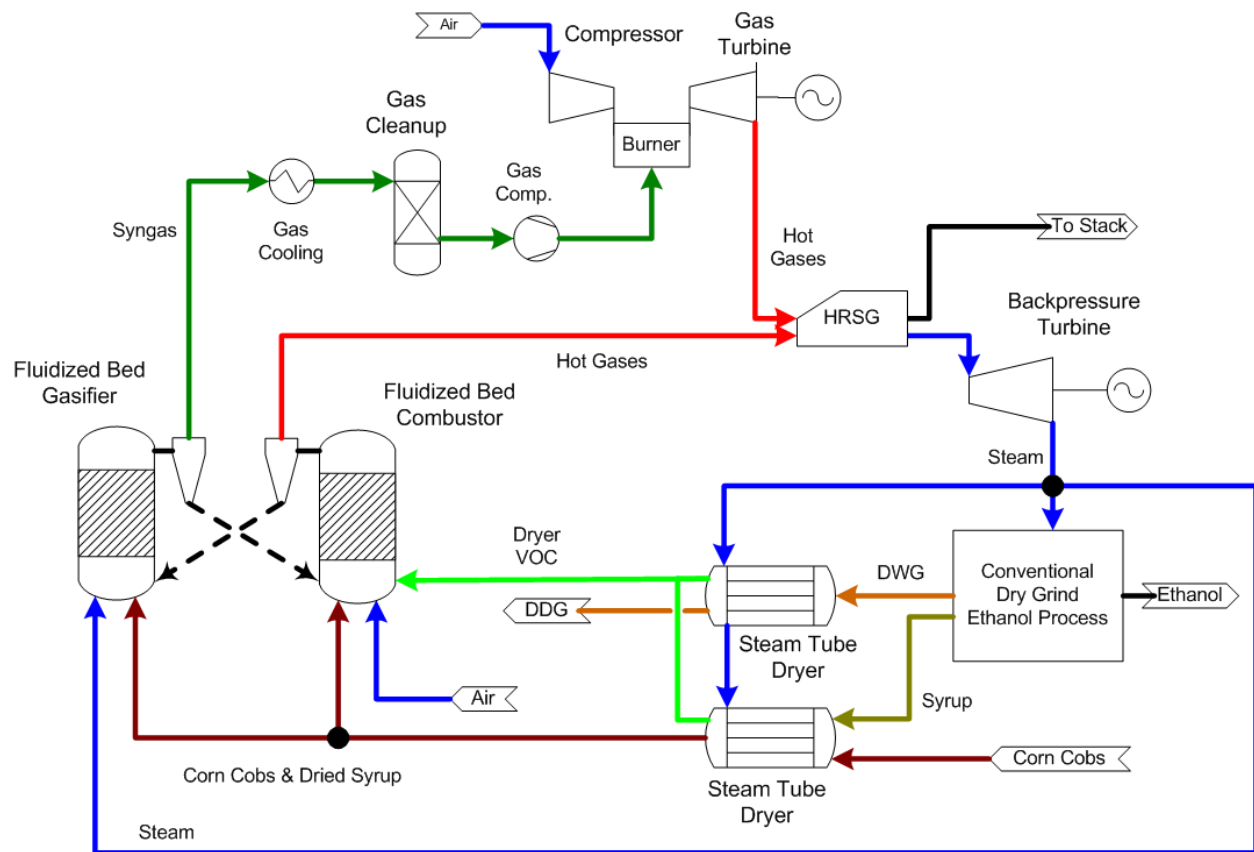


Figure 1. Biomass Integrated gasification combined cycle system diagram.

Preliminary results indicate that approximately 30 MW_e of power can be generated at a 50 million gallon per year plant. Power generation efficiency is 28% and system thermal efficiency is 71%.

1B Gasification – gas cleanup modeling and technology evaluation

- Begin modeling gasifier performance
- Begin fuel and emissions analysis

The fluidized bed gasifier is shown schematically in Figure 1. We have a preliminary model of gasifier performance, which allows us to predict energy production. That model is being further developed to allow modeling of synthesis gas production and cleanup. Modeling of emissions from the stack is also underway.

1C Integration of super heated steam dryer technology

- Begin modeling characteristics that impact the ethanol process

Super heated steam dryers will replace the steam tube dryers shown schematically in Figure 1. Process steam will flow to the dryers to produce superheated steam. Water vapor removed in the distillers wet grains (DWG) or the syrup dryers will mix with the superheated steam. The mixture of superheated steam and water vapor will be cooled and condensed. The condensed mixture will be separated into a relatively clean stream that flow back into the process and a

dirty stream which will contain volatile organic compounds (VOC) and other materials released in the drying process. This portion will be a feed stream to the combustor where the VOCs and other materials will be destroyed in the high temperature process. There will no longer be an exhaust air stream from the dryer which will flow into the combustor. Modeling of this process has started.

2 Develop and test business model

- Begin specification of key elements
- Begin grid evaluation and feasibility study

This section of the report was prepared by Larry Schedin, LLSResources.

I. Introduction

Investment and operating costs for a BIGCC project are forthcoming from the research and engineering parts of the project which will develop and measure a simulation model that works efficiently. However, commercial application must reflect the decision criteria, including risks and rewards, of the parties who are likely to finance and own the project as well as the technology. Business models often begin with life cycle analysis models constructed in academia or within governmental agencies to measure net societal benefits of a new technology. However, the decision to actually invest in the technology typically depends on application of financial decision models used by investors and owners along with their perception and measurement of financial risk.

This chapter examines financial models applied by entities most likely to bring the BIGCC concept to commercial operation. These include: 1) public agencies, 2) municipal, REA Co-ops, and other publically owned utilities, 3) investor-owned utilities (IOU's), and 4) private developers. There are of course possible hybrids of these potential ownership entities, but the approach used in this chapter is to develop models typically used by each.

II. Business Model Alternatives

Public Agencies - Project Examples

The Twin Cities Metropolitan Council Environmental Services (MECS) recently constructed a 5,000 KW electric power generating facility powered by steam from several fluidized bed boilers burning sludge from the treatment process at its main metro plant south of St Paul, MN. During cold weather months, the steam is used to heat the wastewater treatment process rather than to produce electricity

Basic Business Model

This not-for-profit business model uses low-cost, 100% debt financing including tax-free municipal bonds, clean renewable energy bonds (CREBS), program incentive payments, and other debt financing backed by the funding authority of the Metropolitan Council, a unit of government set up by state statute. (We will describe in detail how these financing mechanisms work). The income portion of the model is typically driven by fuel and O &

M savings resulting from a project. We will show how this model works as applied to a typical project, to be confirmed by the Finance Director for MCES

Municipal, REA Co-ops and other publically-owned utilities - Project Examples

Selected examples include a) the 400 KV DC (plus and minus) transmission line constructed by United Power Association and Cooperative Power Association (forerunners of Great River Energy) from Coal Creek Power Station in North Dakota to Watertown, MN, b) the Spiritwood, ND Station Project presently being developed by Great River Energy in cooperation with Cargill Malt, c) the City of Moorhead wind turbines, and d) the Hibbing-Virginia wood burning biomass project under contract with Xcel Energy.

Basic Business Model

These projects are typically financed with 100% debt backed by REA (now RUS) federal agency loan guarantees, credit of the member co-ops, municipalities, etc. Income results from sales contracts for steam supplied to site host and electric sales to member customers.

Investor-Owned Utilities - Project Examples

Grand Meadow wind farm is the first wind farm to be owned and operated by Xcel Energy. Xcel Energy's other wind resources are all owned by entities separate from Xcel, and Xcel purchases the output under a Power Purchase Agreement. Other examples include combustion turbine projects such as Blue Lake, Anson and the Metropolitan Emission Reduction Project (MERP).

Basic Business Model

The Integrated Resource Planning procedure mandated for utilities under MN state law is important for evaluating these models. The Renewable Energy Standard applicable to all MN utilities under state law along with Xcel's obligations and the separate obligations of other MN utilities impact this model. We will analyze the eligible fuels which meet the standard and the resulting Renewable Energy Credits (REC's) created both because of MN mandates along with mandates in other states.

Private Developers - Project Examples

Private developers have opportunities to optimize tax credits and other incentives. Third party wind farms, large Independent Power Producer projects (IPP's) such as those by NRG, and the new Collville Peaking plant near Red Wing, which has a power purchase agreement with Xcel are examples.

Basic Business Model

Debt/equity financing with expected equity returns backed by sales contracts are important for private developers. Recent changes in tax laws and new incentives for renewable power are critical elements for this business model.

III. Application of the Business Model Examples to the BIGCC Project

Environmental , economic development, potential tax benefits and other benefits of the BIGCC Project:

- Importance of Key Variables
- Sensitivity analyses
- Application of risk analysis as a measurement tool
- Results of model simulations
- Recommendations

3 Analysis of a biomass procurement system

- Begin development of specifications

Introduction

Users of biomass need a consistent supply throughout the year. However, in the Upper Midwest collection/harvesting of herbaceous biomass is limited to certain times of the year, usually late summer or fall. A system is needed to collect, store, accumulate, process, densify (briquette or pellet), and deliver consistent, dense, free-flowing material to the users throughout the year. Collection/harvesting occurs on an agricultural cycle (late summer or fall time frame). The user of biomass operates on an industrial cycle (year around time frame). A key component requiring new approaches is the step involving accumulation of biomass stored at numerous field or farm sites and delivery to a processing facility or end user throughout the year in a form that is easy to handle and efficient to transport. One concept is to take bales stored at individual farm sites, chop or coarsely grind the biomass, then compact it to a bulk density of at least 240 kg/m³ (15 lb/ft³), and load it on trucks for delivery as a bulk product. Achieving a bulk density of at least 240 kg/m³ (15 lb/ft³) allows for transport of biomass in trucks that will load out based on maximum weight rather than volume.

The Proposed System

We propose a system for delivering densified biomass that has the following major components with some potential alternatives identified under each.

Collection/harvesting (cutting/shredding, raking, round bales)

- corn stover – fall
- native grass or switchgrass – fall
- straw – late summer
- alfalfa for fuel – mid summer and early fall

Storage within days after baling, near the field – local storage

- store as round bales near the field or a farmstead close to several fields

Process (bale to bulk) at local storage and transport to the end user, which could be a processing/densification facility or other large user such as an ethanol plant.

- grind with a tub grinder or similar machine and transport as coarsely ground bulk material. Some compaction may be required at this step to achieve a bulk density of at least 240 kg/m³ (15 lb/ft³) to facilitate truck transport in 25 ton loads. Mobile equipment, including tub

grinder, roll-press compactor and loader tractor move from one local storage site to another to provide a steady flow of compacted biomass to the end user. It is assumed that a “drop trailer” (empty) is always available at the local storage sites to be filled with compacted material.

- operate year around, grinding the wettest material, perhaps corn stover, during the November through March period to reduce spoilage and associated dry matter losses.
- if bales lose quality or shape during the local storage period, processing from bale to bulk will eliminate problems with transportation of irregularly shaped bales.

Processing/densification either at a separate facility or as part of a large end user’s (e.g. ethanol plant) operation

- facility operates year around drawing from a 20 to 50 mile radius
- system to tub grind, compact, and transport material staged to provide material throughout the year with storage for several days of operation at the facility
- processing includes further size reduction, drying (if needed), or possible mixing to achieve desired moisture (20% moisture into briquetting or pelleting equipment)
- densification includes briquetting or pelleting to achieve a bulk density of 25 to 35 lbs per cubic foot at 12 to 15% moisture

Storage (after densification)

- storage of briquettes or pellets until delivery to the user
- storage could be at the densification facility or at the end user

Transportation/delivery to the user

- transport by truck at 25 to 35 lbs per cubic foot (briquettes or pellets)

Progress to Date

We have focused on the following components of the proposed system.

- Logistics associated with collection including shredding, raking, baling, and bale moving of corn stover to a local storage within 1 to 2 miles of the field immediately after corn grain harvest in the fall. We also considered nutrient replacement for the material removed.
- Bale to bulk processing at the local storage including tub grinding, roll compaction to 240 kg/m³ (15 lb/ft³), and loading trucks.
- Truck transport in 25 ton loads to end users.

Preliminary results include the following. The total cost, fossil energy consumption, and fossil CO₂ emission for delivering the bulk corn stover to end users was \$77/ton, 982 MJ/tonne, and 62 kg CO₂/tonne, respectively, including nutrient replacement. The total fossil energy consumption is equivalent to approximately 5.8% of the energy content of the biomass. The corresponding life-cycle fossil CO₂ emissions are 3.65 g CO₂/MJ of corn stover for heat and power applications. Our estimates show that for heat and power fuel applications, corn stover reduces life-cycle fossil CO₂ emissions by factors of approximately 15 and 25 compared to natural gas and coal, respectively.

4 Outreach and education for investors, policy makers, utilities and the public

- Update web site
- Begin development of models, spreadsheets and other decision aids

We updated the web site to reflect the new project. All materials from the previous project are also maintained on the web site at a clearly defined location.

A spreadsheet model for the biomass logistics system is under development. We are using it to generate our results for our analysis, but it is being developed in a format that will allow us to make it available to a variety of users as the project progresses.

Project Status

Overall we are making good progress. The work undertaken by Matt De Kam during the period between projects while he was finishing his masters degree thesis gave us a good start on Task 1A, Integrated gasification combined cycle analysis. However, we lost most of our expertise in Aspen Plus modeling when Matt left, so it has taken us some time to bring new people up to speed in this activity. We are now making good progress in this area and will be able to draw on the work that has already been completed.

We are probably a bit ahead of schedule on Task 3, Analysis of a biomass procurement system, because another project that we were able to work on between the end of the last project and the beginning of this project had some elements that contributed to this activity.

We signed contracts with our subcontractors, LLS Resources, LLC and AMEC E&C Services Inc. Copies of those contracts are attached.