METHOD 2B PATHWAY

CALIFORNIA LOW CARBON FUEL STANDARD

GENERAL INFORMATION

Applicant: Archer Daniels Midland Company
4666 Faries Parkway
Decatur, IL 62526
LCFS Business Partner ID Code: 4888 (same as EPA Code)

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BACKGROUND

Archer Daniels Midland Company (ADM) has constructed two new dry mill facilities. One facility is located in Columbus, Nebraska and the other facility is located in Cedar Rapids, IA. Both facilities are located adjacent to an ADM corn wet mill and a combined heat and power plant. Combined heat and power is also commonly referred to as cogeneration. These "sister" dry mill facilities also have similar design and operational characteristics. However, the Cedar Rapids, IA facility does have some differences from Columbus such as fuels combusted in the cogeneration. As a result, this submission only addresses the Columbus, NE dry mill at this time. Based on communications with CARB, this application will be updated to include the Cedar Rapids, IA facility in the near future.

These plants have three unique processes for dry mills, which form the basis for the new pathway request and these include the use of advanced process technology and heat integration for reduced process energy, solid fuel fired cogeneration, and specifically co-firing of biomass. Additional information is provided for each of these in this application.

Due to these factors, there is not a current pathway that accurately describes these new dry mills. There isn't a pathway for any dry mill that uses coal and/or cogeneration and the energy requirements used to establish the current pathways are significantly different than these new facilities. Therefore, the Method 2B application requests a new pathway for these processes.

This document has the trade secret / confidential information redacted. The information reported under the contact information in this application should be used if there are questions concerning it.

I. Application Submission Date: November 5, 2010

II. Company Contact Information

a. Company Name: Archer Daniels Midland Company

b. Mailing Address:

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State/Province	IL
Zip/Postal Code	62526

c. Main Company Phone Number: 800-637-5843

d. Secondary Company Phone Number: 217-424-5200

e. Fax number: 217-451-7415

f. Company Web Site URL: www.adm.com

g. Primary Method 2A/2B Contact Person:

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h. Consultant/Third Party Application Preparer:

Name: n/a

Position/Title: n/a

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Office Phone Number: n/a

Mobile Phone Number: n/a

Fax Number: n/a

Consulting entity's web site URL: n/a

i. LCFS Reporting Tool Organization ID code (if known):

j. U.S. Environmental Protection Agency (U.S. EPA) Company ID (if known): 4888

k. U.S. EPA Facility ID (if known):

III. Pathway Information

a. Pathway application type. Applicants are encouraged to discuss their pathway application types with ARB staff before proceeding. Please check one box only.

☐ Method 2A: Sub-pathway ☒ Method 2B: New Pathway

b. Brief description of proposed pathway. Please emphasize the important innovations and/or distinctive characteristics associated with the proposed pathway or sub-pathway

The proposed pathways are based on ADM design information considering equipment and operational constraints. The operational constraints are based on annual average values (e.g., 27 % overall feed moisture) and average ethanol production of 851,307 gallons per day for 352 days per year. Carbon Intensities from CA-GREET are noted in parenthetical following each pathway. Additional details regarding the pathways are found later in this document.

Pathway:

1. Midwest, Dry Mill, Dryer Closed-loop Heat Recovery, Cogeneration - Coal (91.00)
    a. Supplemental fuel pathway: 5% biomass (89.09)
    b. Supplemental fuel pathway: 10% biomass (87.17)
    c. Supplemental fuel pathway: 15% biomass (85.25)
2. Midwest, Dry Mill, Dryer Closed-loop Enhanced Heat Recovery, Cogeneration – Coal (90.11)
    a. Supplemental fuel pathway: 5% biomass (88.16)
    b. Supplemental fuel pathway: 10% biomass (86.22)
    c. Supplemental fuel pathway: 15% biomass (84.27)

c. For Method 2A Applications only

1. Reference pathway (Existing fuel pathway to which the proposed new sub-pathway is most closely related). The carbon intensity of the reference pathway must be higher by at least 5 gCO_2e/MJ than the carbon intensity of the proposed pathway described in this application. Show all pathway information exactly as it appears in the LCFS Lookup Table:

   Fuel: n/a

   Pathway Description: n/a

   Carbon Intensity Values (gCO_2e/MJ): n/a

   Direct Emissions: n/a

   Land Use or Other Indirect Effect: n/a

   Total: n/a

2. Compositional differences (if any) between the fuel produced by the new sub-pathway and the reference pathway identified in item c, 1, above).

n/a – Method 2B

d. Final carbon Intensity of the proposed pathway or sub-pathway:

See question III.b.

e. Annual volume of fuel that would be produced using the proposed new sub-pathway (millions of gallons per year [MGY]).

The Columbus dry mill is permitted to produce approximately 400 MGY.

1. This production volume is expected to be achieved within how many years from the start of production?

   The facility commenced operations and typical rates are expected to be achieved during 2011.

2. Does the applicant expect this volume be achieved by a single or by multiple facilities?

   ☒ A single facility ☐ Multiple facilities

3. If the applicant expects this volume to be achieved by multiple facilities, would all facilities be owned by a single firm?

   ☒ Single firm ☐ Multiple firms

f. Lower Heating Value of the fuel to be produced from new sub-pathway (megajoules per gallon):

   Undenatured Ethanol – 80.53 megajoules per gallon

g. The range of production volumes over which the proposed pathway carbon intensity value is valid. The values reported below must be supported in the documentation accompanying this application.

	Fuel Volume	**Units (gallons; litres; joules,etc.)**
Lower bound of production volume range	0	Gallons
Upper bound of production volume range	400	Million Gallons per year per facility

h. Please provide any information that may be helpful in determining the land use change impacts (if any) of the proposed pathway. Although it is ARB's responsibility to perform all land use change impact analyses, the applicant may provide any information that may be useful to the ARB in completing that analysis.

This new pathway will not change the land use impacts for corn ethanol.

IV. Application Submittal Checklist. Listed below are the documents and files that may be submitted in support of a method 2A/2B application. Check the box to the left of each document or file type included in your submittal. After each submittal category is a check box labeled "includes trade secrets." Check that box if the submittal category contains any information the applicant considers to be a trade secret. In the actual submittal, the specific information falling into the trade secret category must be clearly marked. Additional information regarding the submission of trade secrets can be found in the Instructions above.

- ☐ Life cycle analysis report
    - ☐ *Includes trade secrets*
- ☐ Engineering reports
    - ☐ *Includes trade secrets*
- ☐ Equipment technical specifications
    - ☐ *Includes trade secrets*
- ☒ Production process schematics, technical drawings flow diagrams, maps, or other graphical representations
    - ☒ *Includes trade secrets*

- ☐ Technical papers or journal articles
  - ☐ *Includes trade secrets*
- ☐ Emissions monitoring data or emissions modeling results
  - ☐ *Includes trade secrets*
- ☐ Spreadsheets, data files, and similar files documenting the calculations behind the fuel life cycle analysis
  - ☐ *Includes trade secrets*
- ☐ Other: In the space below, describe any additional submittals. Rationales for documents submitted or omitted may also be provided.
  - ☐ *Includes trade secrets*

ARB Method 2A and 2B Application Process Contacts

Name	Phone Number	E-mail Address
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ADM DRY GRIND ETHANOL PROCESS DESCRIPTION

Utilizing the dry-grind method of ethanol production, processors can produce about 2.7 gallons of ethanol from a bushel of corn. Continued improvements to process will move this number closer to 2.8 in near future. But current plant design energy numbers are based on the 2.7 to be conservative. Overall the ADM dry mill process operation is similar to those reviewed by CARB for the other ethanol pathways with the exceptions noted below which includes the heat recovery systems for distillation/dehydration, evaporation, and co-product drying. A process flow diagram that generally corresponds to the process steps below is attached as Figure 3. This figure also identifies the major combustion sources (i.e., dryers, flare, RTO) in the dry mill by the fuel input labels which are all natural gas. Typical natural gas usage for the dry mill is shown in Figure 4. Combustion sources for the Cogeneration facility are discussed under that section.

CORN MILLING

In the ADM facility the entire corn kernel is ground into a coarse flour, then slurried with water to form a "mash." The mash is then cooked, treated with enzymes, fermented and distilled. Products of the dry-grind process include distillers grains and ethanol.

STARCH CONVERSION

Corn endosperm starch cannot be utilized directly by yeast. It must first be broken down into simple sugars prior to fermentation. In order to accomplish this conversion, enzymes are added to the mash during cooking. The first step in breaking down the starch molecule utilizes an alpha-amylase enzyme and steam (gelatinization and liquefaction). The next step involves adding gluco-amylase enzymes at a lower temperature to produce smaller fermentable sugars (saccharification). ADM utilizes continuous cooking which is generally more energy efficient as the flash steam can be used as heat source directly in the process from this unit operation. Discharge from this steam heated source is also heat recovered via a series of heat exchangers to minimize steam usage.

FERMENTATION

After starch conversion has been initiated, the mash is transferred to fermenters where yeast (*Saccharomyces cerevisia*) is added to the converted corn endosperm starch to produce ethanol.

ADM utilizes a continuous fermentation system in order to minimize hardware and water usage which in turn reduces the overall plant evaporation and distillation energy requirements.

DISTILLATION AND DEHYDRATION

Distillation is the process of separating the ethanol from the solids and water in the mash. Conventional distillation/rectification methods can produce 95% pure (190 proof) ethanol. In the ADM design there is a reduction in energy in running lower proof off the rectifier and utilizing the addition of pressurized 3 bed molecular sieve system. [redacted] The rate of this undenatured Ethanol is [redacted] gallons per hour. Condensing this source is [redacted] BTU/hr. When you divide this BTU/hr number by production non-denatured gallons per hour you get [redacted] BTU/gallon undenatured ETOH energy savings utilizing this improved molecular sieve system with heat recovery system. The anhydrous ethanol is then blended with about approximately 2% denaturant (such as gasoline) to render it undrinkable and thus not subject to beverage alcohol tax.

STILLAGE PROCESSING

The solid and liquid fraction remaining after distillation is referred to as "stillage". Stillage includes the fiber, oil and protein components of the grain, as well as the non-fermented starch. The "thin stillage" is separated from the insoluble solid fraction using centrifuges. The thin stillage is then sent to evaporators to remove excess water. In the ADM design this is 3 different reboiler systems.

1. Steam reboiler system
2. Waste heat from Dryer (process steam)
3. [redacted]
4. Stillage (Dedert design) MVR (mechanical vapor recompression) primary evaporation http://www.dedert.com/evaporator.htm
5. This preconcentrated evaporator is then concentrated to final DS target by HPD MVR (mechanical vapor recompression) evaporation system.

FIGURE 1 Stillage evaporation system including falling film evaporator train and high solids concentration system (reference: http://www.hpdsystems.com/en/industries/industrysolutions/ethanolbiofuels/)

Published and Documented MVR Evaporation Benefits:

- Steam and overall energy consumption was significantly reduced compared to conventional steam heated evaporator systems with the same capacity.
- Cooling water requirements were reduced
- The main vacuum system for the evaporator system was reduced in horsepower, capacity and size compared to one required without use of a MVR
- Higher condensate temperatures provide additional steam savings by providing hot water (185-190 F) source for use in the process.

After evaporation, the thick, viscous syrup is mixed back with the solids to create a feed product known as Wet Distillers Grains with Solubles (WDGS).

FEED PRODUCTS FROM STILLAGE PROCESSING

WDGS, containing 65% moisture, can be used directly as a feed product. In fact, it is often favored by dairy and beef feeders because cattle seem to prefer the moist texture. However, WDGS has a shelf life of only one to two weeks. To increase shelf life and lower transportation costs, WDGS is usually dried to 10 to 12% moisture to produce a product known as Dried Distillers Grain with Solubles (DDGS). Drying distillers grains is energy-intensive, consuming about one-third of the energy requirements of the entire dry-grind plant. With recent technology improvement and closed loop superheated steam dryers this energy is recovered [redacted] area to displace traditional steam from boilers or Cogeneration in the case for the Columbus facility.

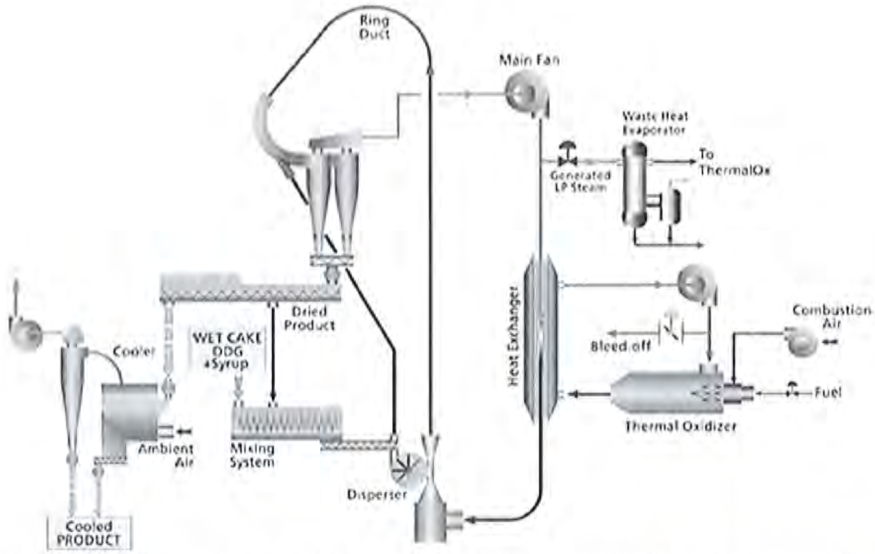


FIGURE 2 Indirect-fired SSD dryer – ring (reference: http://www.barr-rosin.com/applications/solids_drying.asp)

This is an important breakthrough as producing a uniform, stable, high-quality feed co-product is essential to the profitability of the plant. The Columbus NE facility has the advantage of a very well developed, local wet feed market for cattle. Design for the Columbus, NE facility is yearly average moisture of [redacted]. Steam from the feed dryers is condensed in reboilers [redacted]. At a [redacted] Wet Bulb (or higher based on recent information) this condensed approximately [redacted]% of steam from this source according to process instrumentation and Aspen model validation. Or in energy terms we generate [redacted] lb/hr steam at [redacted] psig. Condensate from reboilers would be [redacted] lb/hr or [redacted] BTU/hr recovered to process. When you divide this BTU/hr number by production non-denatured gallons per hour you get [redacted] BTU/gallon undenatured ETOH energy savings utilizing this improved drying technology. This range of BTU per gallon is substantiated in the article at the following link.
http://www.usda.gov/oce/reports/energy/2008Ethanol_June_final.pdf

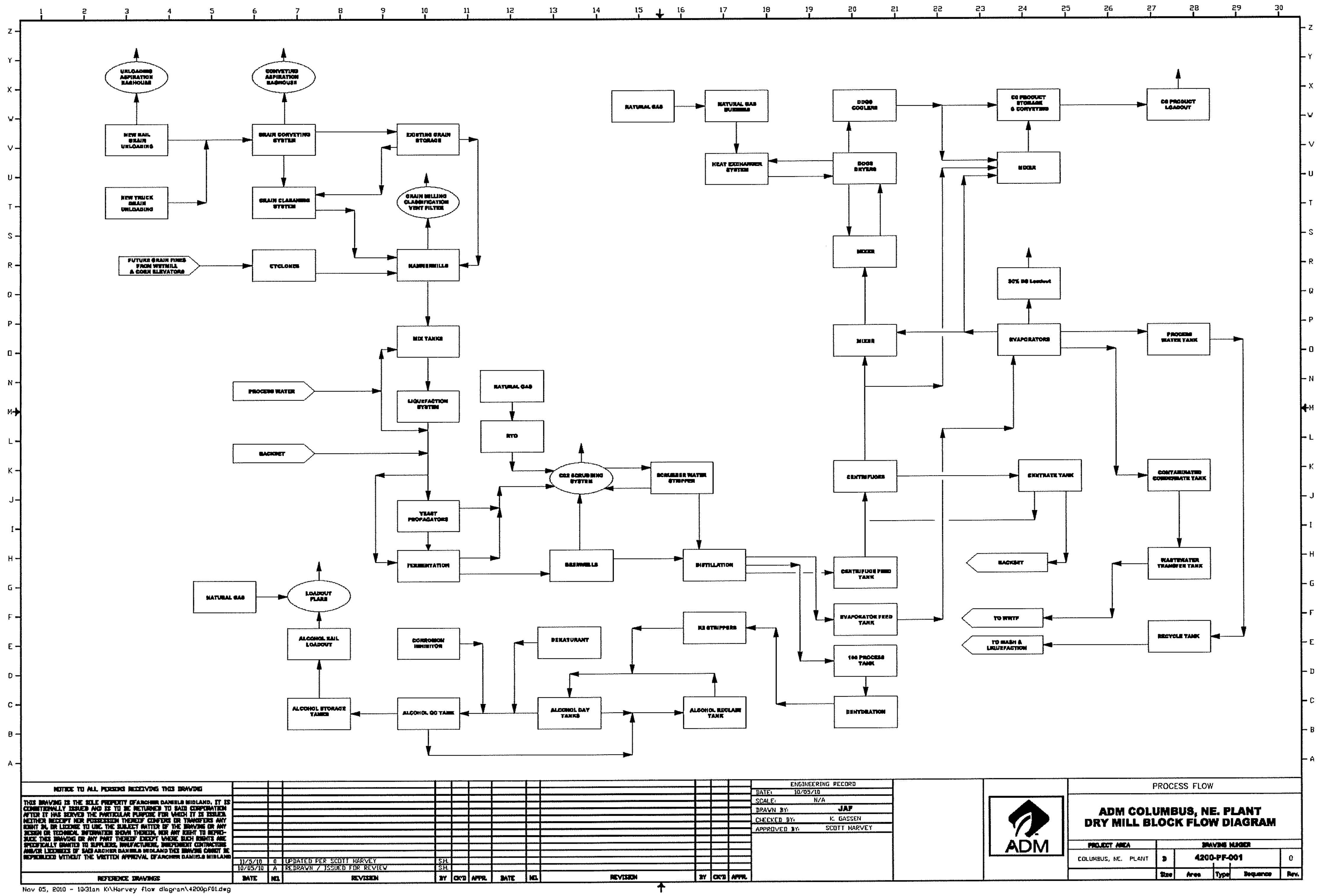


FIGURE 3 ADM Columbus Dry Mill Process flow diagram

ADM DRY MILL ENERGY BTU PER GALLON CALCULATION

In reviewing the USDA model for Dry Grind ETOH it is clear from this model that the Dryer steam is not recovered and hence accounts for the majority of the difference between the ADM design and the results presented in this effort. In the USDA model Ethanol final product is condensed on the regeneration stream from a molecular sieve. ADM uses this heat to directly displace steam in distillation reboilers and is able to preheat the same purge stream at the same time. It is able to accomplish this because of the difference in evaporation types. ADM utilizes a Mechanical Vapor Recompression (MVR) evaporator whereas the USDA utilized a less capital intensive and operationally intensive multi-effect evaporator. The difference of the two approaches is that ADM has a much higher temperature condensate to be used back in the process. This excess heat allows the ethanol final product to reduce the BTU/gallon ethanol number as detailed below. Contrasting the USDA model to ADM's more capital intensive facilities, suggests that ADM has installed and utilizes several additional heat recovery heat exchangers beyond the USDA more basic design.

The typical Midwest ethanol dry mill analyzed in CA Greet uses 36,000 BTU/Gallon which is also consistent with the USDA model for dry mill ethanol plants. These plants do not incorporate the dryer steam heat recovery or the distillation/dehydration heat recovery. Subtracting the energy savings associated with these technologies results in a value equivalent to the ADM design value.

Typical Midwest Dry Mill	36,000	btu/gal
Dryer Heat Recovery	[redacted]	btu/gal
Distillation/Dehydrations Heat Recovery		btu/gal
Typical Midwest Dry Mill w/ADM Heat Recovery		btu/gal
ADM Dry Mill Design Value (facility gate)	[redacted]	btu/gal

Due to the heat recovery integration, particularly the heat from the dryer system, there is minimal difference in the overall plant energy demand whether wet or dry feed is produced. The reason for this is the steam produced in the closed-loop dryers is displacing steam required from the coal boilers. The closed-loop dryer natural gas burners have a higher efficiency than the coal fired cogeneration boilers. As summarized below there is only a [redacted] btu/lbs steam or about 2% difference between distillation steam supplied by the cogeneration boilers versus steam generated from the dryers.

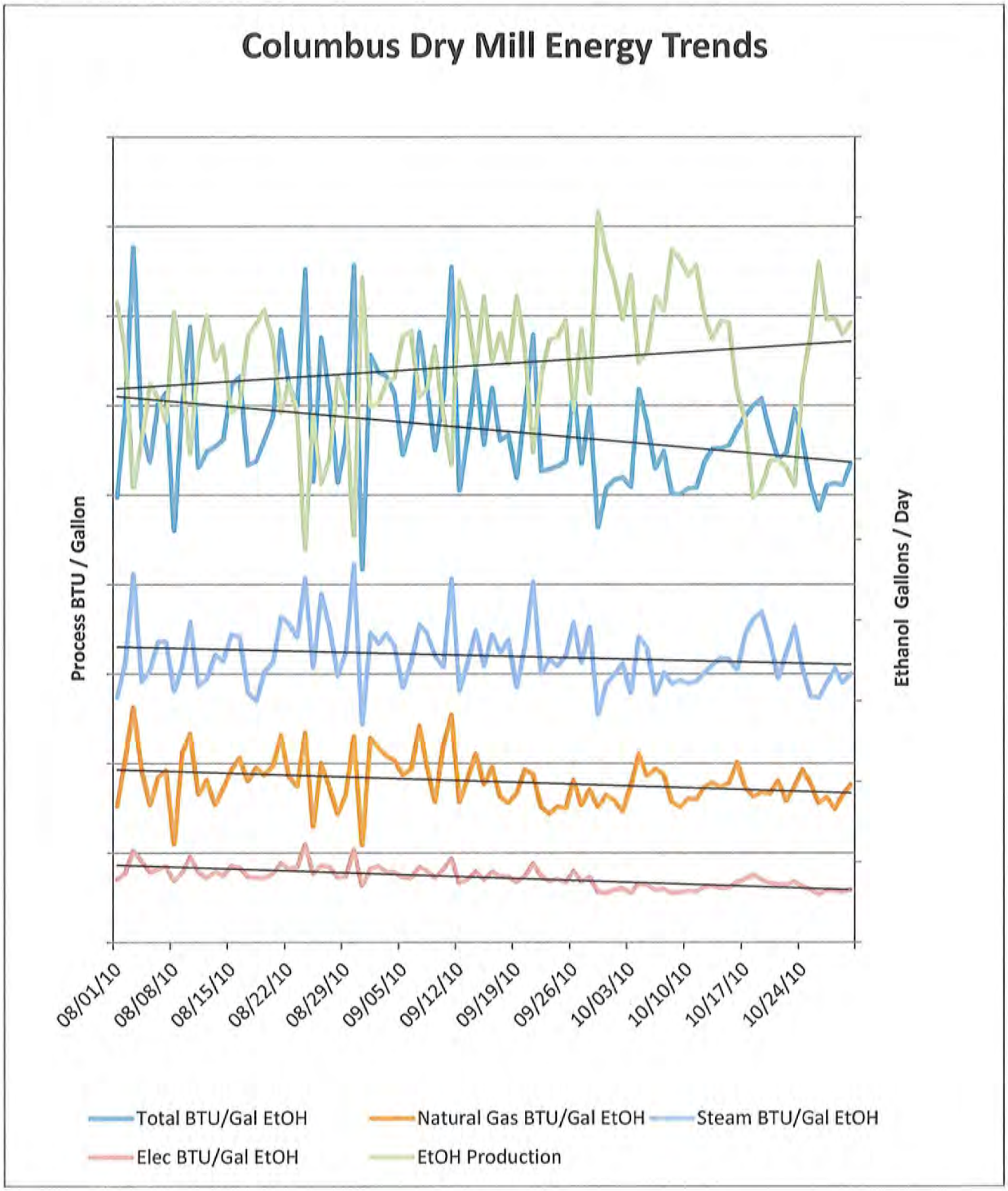
<u>Cogeneration Steam BTU required/lb Steam in</u> [redacted]

[redacted]%	Cogeneration Efficiency
970	BTU/lb water condensed
1293.33	Required Coal BTU's for 970 BTU/lb steam
[redacted]%	Dryer Efficiency
[redacted]	BTU/lb Water Evaporator in Dryer
[redacted]	Percent that can be condensed in [redacted] at [redacted] Wet Bulb (worst case)
[redacted]	Equivalent BTU input required per usable lb steam in [redacted] via Dryer steam Discharge
[redacted]	Difference in BTU/lb steam [redacted].

ADM produces different feed products and is continually working with customers to develop new blends to meet their needs. These products include Distillers Dry Grain Solubles, 40 DS Modified, 60 DS Modified, Corn Condensed Distillers Solubles and a modified blend with wet mill wet feed called Golden Synergy. The type of feed product produced varies at any given time based on market demand, equipment operations and other issues which many times cannot be controlled by the facility. Market demand and moisture tolerances can also vary depending on the time of year. Because of the interdependency of operations for feed and ethanol production, minimal difference in energy required to produce the different feed products, the ability to obtain an accurate energy split between feed products and market variability, ADM does not differentiate in energy for each product.

Figure 4 represents the most recent snapshot of energy tracking for the facility. As indicated by the trend line, the energy usage continues to improve as the facility continues through the start-up process. As the ethanol production rate increases, there is a corresponding decrease in energy per gallon. This is due to the increased efficiencies of operating at a higher rate. As the start-up issues are addressed the production rate will continue to increase and stabilize.

FIGURE 4 Columbus Dry Mill Energy Tracking



COGENERATION / COMBINED HEAT AND POWER

Cogeneration (COGEN) or combined heat and power (CHP) plants allow a simultaneous production of electricity and useful thermal energy (steam) using a single source of primary energy (natural gas, coal, biomass) and offers significant efficiency improvements over separately producing same amounts of electric and thermal energy. Figure 5 below describes the efficiency improvements for a COGEN plant in comparison to individual heat and power plants.

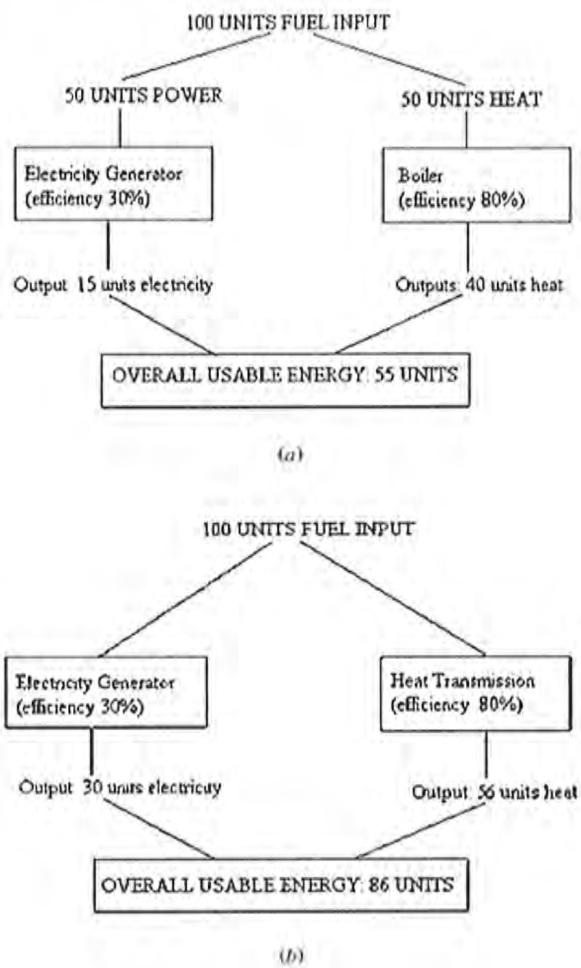


FIGURE 5 COGEN Efficiency Improvements: (a) Separate heat and power system with 100 units fuel inputs; (b) Combined heat and power (COGEN) system with 100 units fuel inputs. (1)

Such a plant offers excellent synergies for large chemical plants with multiple production facilities (e.g. Combined Petroleum Refinery & Petrochemical Complex). ADM's operations in Columbus, NE can be considered analogous to a Petroleum Complex, with a Wet Mill and Dry Mill co-located on the same site.

In such an operation, steam and electricity generation can be optimized to meet process energy demands from various onsite plants and at the same time, it provides COGEN the flexibility to meet these demands without sacrificing optimal performance.

The cogeneration (COGEN) plant at Columbus, NE serves the dry and wet mill operations. The steam produced from the COGEN is capable of supplying the needs for the Dry mill and Wet mill. However, COGEN electricity is solely consumed by the dry mill and any additional electricity that may need to be purchased would be for the wet mill.

The Columbus COGEN plant is comprised of two high-pressure circulating fluidized bed (CFB) boilers with a single backpressure turbine generator. The CFB boilers are currently fueled by North Antelope Rochelle mine coal, which is located in the Powder River Basin (PRB) region of United States. These boilers are designed and permitted to co-fire up to 20% biomass with coal. While no co-firing has been done so far in Columbus, dried biomass from the onsite process wastewater treatment plant, agricultural seeds and corn stover have been co-fired in Cedar Rapids COGEN, without any difference in its performance.

The combination of high-pressure boilers and backpressure turbines are proven to provide significant efficiency improvements and cost savings over conventional low pressure boilers (2). Columbus COGEN operation in its current operation has an overall efficiency of approximately [redacted]%[a] .

Columbus COGEN operation is working to increase the co-firing of biomass fuels such as agricultural seeds, dried waste biomass, and other sources of biomass, which will further reduce CO_2 emissions from cogeneration of steam and electricity, because of the carbon-neutral nature of such biomass sources. It is important to note that seed being burnt in COGEN is generally end of year inventory of unsold seed or out of specification which historically has been managed through incineration.

[a] COGEN Efficiency = (Dry Mill Steam BTU+Dry Mill Electric BTU+Wet Mill Steam BTU)/(Coal BTU+Dry Mill Condensate Return BTU+Wet Mill Condensate Return+Make-up water BTU)

Table 1 lists the user design inputs that were changed in CA-GREET for ADM pathway Midwest, Dry Mill, Dryer Closed-loop Enhanced Heat Recovery, Cogeneration – Coal and the biomass pathways. All other parameters are unchanged for the proposed sub-pathway including raw materials, ethanol energy content and land use change.

TABLE 1 User design inputs for CA-GREET and ADM Pathway MIDWEST, DRY MILL, DRYER CLOSED-LOOP ENHANCED HEAT RECOVERY, COGENERATION - COAL

CA-GREET Worksheet	Cell Reference	Input	Units	CA-GREET Value	ADM Pathway 1 Value
Inputs	B4	Target Year of Simulation		2010	2010
Fuel_Prod_TS	C271	EtOH Yield of Corn Dry Mill EtOH Plant	gal/bushel	2.72	2.70
Inputs	C244, D244	Share of corn ethanol plant types	%	85% dry mill, 15% wet mill	100% dry mill, 0% wet mill
Fuel_Prod_TS	K271	Total ethanol energy use (undenatured)	BTU/gal	36,000	[redacted]
Inputs	C247	Electricity share of process fuel	%	10.2%	0%
Fuel_Prod_TS	S271	Share of Coal in total process fuels	%	20%	Base: 68.35% 5% Biomass: 62.30% 10% Biomass: 56.24% 15% Biomass: 50.18%
Inputs	C255	Share of NG as Process Fuel	%	100%	31.65%
Inputs	C256	Share of Coal as Process Fuel	%	0%	Base: 68.35% 5% Biomass: 62.30% 10% Biomass: 56.24% 15% Biomass: 50.18%
Inputs	E255	Biomass as Process Fuel	%		Base: 0% 5% Biomass: 5% 10% Biomass: 10% 15% Biomass: 15%
Inputs	C262	Share of Biomass used as process fuel: Corn Stover	%	100%	100%
EtOH	C101	DGS Yield	bone-dry lb. per gallon EtOH	5.34	5.87

CA-GREET Worksheet	Cell Reference	Input	Units	CA-GREET Value	ADM Pathway 1 Value
Regional LT	H192	Midwest – Coal LHV	BTU/short-ton	19,546,300	16,497,700
Regional LT	H193	Midwest – Coal HHV	BTU/short-ton	20,608,570	17,366,000
Regional LT	H194	Midwest – Coal Carbon Content	% wt	63.7%	47.8%
Regional LT	H195	Midwest – S ratio	ppm by wt	11,100	4,000

TABLE 2 Total Well to Tank (WTT) emissions for Dry Milling Corn Ethanol production under ADM Pathway MIDWEST, DRY MILL, DRYER CLOSED-LOOP ENHANCED HEAT RECOVERY, COGENERATION - COAL

Results are specified as BTU or grams per MMBTU of Ethanol	Corn Ethanol: Dry Milling Ethanol			Total WTT (well to tank) results
	Corn w/o loss factor	Corn w/ loss factor	Ethanol	
Loss factor			1.001	
Total energy	181,068	181,159	[redacted]	[redacted]
Fossil fuels	176,104	176,193	[redacted]	[redacted]
Coal	25,091	25,104	[redacted]	[redacted]
Natural gas	85,581	85,624	[redacted]	[redacted]
Petroleum	65,433	65,466	[redacted]	[redacted]
VOC	16.214	16	54.263	70
CO	146.284	146.358	30.033	176
NOx	70.852	70.888	92.107	163
PM10	7.807	7.811	79.333	87
PM2.5	4.059	4.061	26.015	30
SOx	32.609	32.626	52.749	85
CH4	16.826	16.834	48.317	65
N2O	40.366	40.386	0.257	41
CO2	14,567	14,574	34,263	48,838
GHG Emissions		27,030	35,548	62,578

Total Direct Emissions	59.31	g CO2/MJ EtOH
Land Use Change	30	g CO2/MJ EtOH
Denaturant (CARBOB blended at 2% with anhydrous EtOH)	0.8	g CO2/MJ EtOH
Total Carbon Intensity	**90.11**	**g CO2/MJ EtOH**

TABLE 3 Total Well to Tank (WTT) emissions for Dry Milling Corn Ethanol production under ADM Pathway MIDWEST, DRY MILL, DRYER CLOSED-LOOP ENHANCED HEAT RECOVERY, COGENERATION – COAL AND 5% BIOMASS

Results are specified as BTU or grams per MMBTU of Ethanol	**Corn Ethanol: Dry Milling Ethanol**			**Total WTT (well to tank) results**
	Corn w/o loss factor	**Corn w/ loss factor**	**Ethanol**	
Loss factor			1.001	
Total energy	181,068	181,159	[redacted]	[redacted]
Fossil fuels	176,104	176,193	[redacted]	[redacted]
Coal	25,091	25,104	[redacted]	[redacted]
Natural gas	85,581	85,624	[redacted]	[redacted]
Petroleum	65,433	65,466	[redacted]	[redacted]
VOC	16.214	16	54.255	70
CO	146.284	146.358	30.189	177
NOx	70.852	70.888	91.187	162
PM10	7.807	7.811	73.763	82
PM2.5	4.059	4.061	24.168	28
SOx	32.609	32.626	48.491	81
CH4	16.826	16.834	45.781	63
N2O	40.366	40.386	0.517	41
CO2	14,567	14,574	32,194	46,768
GHG Emissions		27,030	33,493	60,523

Total Direct Emissions	57.36	g CO2/MJ EtOH
Land Use Change	30	g CO2/MJ EtOH
Denaturant (CARBOB blended at 2% with anhydrous EtOH)	0.8	g CO2/MJ EtOH
Total Carbon Intensity	**88.16**	**g CO2/MJ EtOH**

TABLE 4 Total Well to Tank (WTT) emissions for Dry Milling Corn Ethanol production under ADM Pathway MIDWEST, DRY MILL, DRYER CLOSED-LOOP ENHANCED HEAT RECOVERY, COGENERATION – COAL AND 10% BIOMASS

Results are specified as BTU or grams per MMBTU of Ethanol	**Corn Ethanol: Dry Milling Ethanol**			**Total WTT (well to tank) results**
	Corn w/o loss factor	**Corn w/ loss factor**	**Ethanol**	
Loss factor			1.001	
Total energy	181,068	181,159	[redacted]	[redacted]
Fossil fuels	176,104	176,193	[redacted]	[redacted]
Coal	25,091	25,104	[redacted]	[redacted]
Natural gas	85,581	85,624	[redacted]	[redacted]
Petroleum	65,433	65,466	[redacted]	[redacted]
VOC	16.214	16	54.248	70
CO	146.284	146.358	30.345	177
NOx	70.852	70.888	90.267	161
PM10	7.807	7.811	68.192	76
PM2.5	4.059	4.061	22.320	26
SOx	32.609	32.626	44.233	77
CH4	16.826	16.834	43.244	60
N2O	40.366	40.386	0.777	41
CO2	14,567	14,574	30,125	44,699
GHG Emissions		27,030	31,437	58,467

Total Direct Emissions	55.42	g CO2/MJ EtOH
Land Use Change	30	g CO2/MJ EtOH
Denaturant (CARBOB blended at 2% with anhydrous EtOH)	0.8	g CO2/MJ EtOH
Total Carbon Intensity	**86.22**	**g CO2/MJ EtOH**

TABLE 5 Total Well to Tank (WTT) emissions for Dry Milling Corn Ethanol production under ADM Pathway MIDWEST, DRY MILL, DRYER CLOSED-LOOP ENHANCED HEAT RECOVERY, COGENERATION – COAL AND 15% BIOMASS

Results are specified as BTU or grams per MMBTU of Ethanol	Corn Ethanol: Dry Milling Ethanol			Total WTT (well to tank) results
	Corn w/o loss factor	Corn w/ loss factor	Ethanol	
Loss factor			1.001	
Total energy	181,068	181,159	[redacted]	[redacted]
Fossil fuels	176,104	176,193	[redacted]	[redacted]
Coal	25,091	25,104	[redacted]	[redacted]
Natural gas	85,581	85,624	[redacted]	[redacted]
Petroleum	65,433	65,466	[redacted]	[redacted]
VOC	16.214	16	54.240	70
CO	146.284	146.358	30.501	177
NOx	70.852	70.888	89.348	160
PM10	7.807	7.811	62.621	70
PM2.5	4.059	4.061	20.473	25
SOx	32.609	32.626	39.975	73
CH4	16.826	16.834	40.708	58
N2O	40.366	40.386	1.037	41
CO2	14,567	14,574	28,055	42,630
GHG Emissions		27,030	29,382	56,412

Total Direct Emissions	53.47	g CO2/MJ EtOH
Land Use Change	30	g CO2/MJ EtOH
Denaturant (CARBOB blended at 2% with anhydrous EtOH)	0.8	g CO2/MJ EtOH
Total Carbon Intensity	**84.27**	**g CO2/MJ EtOH**

Table 6 lists the user design inputs that were changed in CA-GREET for ADM pathway Midwest, Dry Mill, Dryer Closed-loop Heat Recovery, Cogeneration – Coal and the biomass pathways. All other parameters are unchanged for the proposed sub-pathway including raw materials, ethanol energy content and land use change.

TABLE 6 User design inputs for CA-GREET and ADM Pathway MIDWEST, DRY MILL, DRYER CLOSED-LOOP HEAT RECOVERY, COGENERATION – COAL AND BIOMASS PATHWAYS

CA-GREET Worksheet	**Cell Reference**	**Input**	**Units**	**CA-GREET Value**	**ADM Pathway 1 Value**
Inputs	B4	Target Year of Simulation		2010	2010
Fuel_Prod_TS	C271	EtOH Yield of Corn Dry Mill EtOH Plant	gal/bushel	2.72	2.70
Inputs	C244, D244	Share of corn ethanol plant types	%	85% dry mill, 15% wet mill	100% dry mill, 0% wet mill
Fuel_Prod_TS	K271	Total ethanol energy use (undenatured)	BTU/gal	36,000	[redacted]
Inputs	C247	Electricity share of process fuel	%	10.2%	0%
Fuel_Prod_TS	S271	Share of Coal in total process fuels	%	20%	Base: 63.19% 5% Biomass: 57.51% 10% Biomass: 51.83% 15% Biomass: 46.15%
Inputs	C255	Share of NG as Process Fuel	%	100%	36.81%
Inputs	C256	Share of Coal as Process Fuel	%	0%	Base: 63.19% 5% Biomass: 57.51% 10% Biomass: 51.83% 15% Biomass: 46.15%
Inputs	E255	Biomass as Process Fuel	%		Base: 0% 5% Biomass: 5% 10% Biomass: 10% 15% Biomass: 15%
Inputs	C262	Share of Biomass used as process fuel: Corn Stover	%	100%	100%
EtOH	C101	DGS Yield	bone-dry lb. per gallon EtOH	5.34	5.87
Regional LT	H192	Midwest – Coal	BTU/sho	19,546,300	16,497,700

		LHV	rt-ton		
Regional LT	H193	Midwest – Coal HHV	BTU/short-ton	20,608,570	17,366,000
Regional LT	H194	Midwest – Coal Carbon Content	% wt	63.7%	47.8%
Regional LT	H195	Midwest – S ratio	ppm by wt	11,100	4,000

TABLE 7 Total Well to Tank (WTT) emissions for Dry Milling Corn Ethanol production under ADM Pathway MIDWEST, DRY MILL, DRYER CLOSED-LOOP HEAT RECOVERY, COGENERATION - COAL

Outputs:

Results are specified as BTU or grams per MMBTU of Ethanol	Corn Ethanol: Dry Milling Ethanol			Total WTT (well to tank) results
	Corn w/o loss factor	Corn w/ loss factor	Ethanol	
Loss factor			1.001	
Total energy	181,068	181,159	[redacted]	[redacted]
Fossil fuels	176,104	176,193	[redacted]	[redacted]
Coal	25,091	25,104	[redacted]	[redacted]
Natural gas	85,581	85,624	[redacted]	[redacted]
Petroleum	65,433	65,466	[redacted]	[redacted]
VOC	16.214	16	54.398	71
CO	146.284	146.358	30.307	177
NOx	70.852	70.888	91.872	163
PM10	7.807	7.811	77.452	85
PM2.5	4.059	4.061	25.428	29
SOx	32.609	32.626	51.517	84
CH4	16.826	16.834	50.682	68
N2O	40.366	40.386	0.262	41
CO2	14,567	14,574	35,142	49,716
GHG Emissions		27,030	36,487	63,517

Total Direct Emissions	60.20	g CO2/MJ EtOH
Land Use Change	30	g CO2/MJ EtOH
Denaturant (CARBOB blended at 2% with anhydrous EtOH)	0.8	g CO2/MJ EtOH
Total Carbon Intensity	**91.00**	**g CO2/MJ EtOH**

TABLE 8 Total Well to Tank (WTT) emissions for Dry Milling Corn Ethanol production under ADM Pathway MIDWEST, DRY MILL, DRYER CLOSED-LOOP HEAT RECOVERY, COGENERATION – COAL AND 5% BIOMASS

Results are specified as BTU or grams per MMBTU of Ethanol	Corn Ethanol: Dry Milling Ethanol			Total WTT (well to tank) results
	Corn w/o loss factor	Corn w/ loss factor	Ethanol	
Loss factor			1.001	
Total energy	181,068	181,159	[redacted]	[redacted]
Fossil fuels	176,104	176,193	[redacted]	[redacted]
Coal	25,091	25,104	[redacted]	[redacted]
Natural gas	85,581	85,624	[redacted]	[redacted]
Petroleum	65,433	65,466	[redacted]	[redacted]
VOC	16.214	16	54.391	71
CO	146.284	146.358	30.461	177
NOx	70.852	70.888	90.967	162
PM10	7.807	7.811	71.969	80
PM2.5	4.059	4.061	23.610	28
SOx	32.609	32.626	47.326	80
CH4	16.826	16.834	48.186	65
N2O	40.366	40.386	0.518	41
CO2	14,567	14,574	33,105	47,679
GHG Emissions		27,030	34,464	61,494

Total Direct Emissions	58.29	g CO2/MJ EtOH
Land Use Change	30	g CO2/MJ EtOH
Denaturant (CARBOB blended at 2% with anhydrous EtOH)	0.8	g CO2/MJ EtOH
Total Carbon Intensity	**89.09**	**g CO2/MJ EtOH**

TABLE 9 Total Well to Tank (WTT) emissions for Dry Milling Corn Ethanol production under ADM Pathway MIDWEST, DRY MILL, DRYER CLOSED-LOOP HEAT RECOVERY, COGENERATION – COAL AND 10% BIOMASS

Results are specified as BTU or grams per MMBTU of Ethanol	Corn Ethanol: Dry Milling Ethanol			Total WTT (well to tank) results
	Corn w/o loss factor	Corn w/ loss factor	Ethanol	
Loss factor			1.001	
Total energy	181,068	181,159	[redacted]	[redacted]
Fossil fuels	176,104	176,193	[redacted]	[redacted]
Coal	25,091	25,104	[redacted]	[redacted]
Natural gas	85,581	85,624	[redacted]	[redacted]
Petroleum	65,433	65,466	[redacted]	[redacted]
VOC	16.214	16	54.384	71
CO	146.284	146.358	30.614	177
NOx	70.852	70.888	90.062	161
PM10	7.807	7.811	66.486	74
PM2.5	4.059	4.061	21.792	26
SOx	32.609	32.626	43.135	76
CH4	16.826	16.834	45.690	63
N2O	40.366	40.386	0.774	41
CO2	14,567	14,574	31,069	45,643
GHG Emissions		27,030	32,442	59,472

Total Direct Emissions	56.37	g CO2/MJ EtOH
Land Use Change	30	g CO2/MJ EtOH
Denaturant (CARBOB blended at 2% with anhydrous EtOH)	0.8	g CO2/MJ EtOH
Total Carbon Intensity	**87.17**	**g CO2/MJ EtOH**

TABLE 10 Total Well to Tank (WTT) emissions for Dry Milling Corn Ethanol production under ADM Pathway MIDWEST, DRY MILL, DRYER CLOSED-LOOP HEAT RECOVERY, COGENERATION – COAL AND 15% BIOMASS

Results are specified as BTU or grams per MMBTU of Ethanol	**Corn Ethanol: Dry Milling Ethanol**			**Total WTT (well to tank) results**
	Corn w/o loss factor	**Corn w/ loss factor**	**Ethanol**	
Loss factor			1.001	
Total energy	181,068	181,159	[redacted]	[redacted]
Fossil fuels	176,104	176,193	[redacted]	[redacted]
Coal	25,091	25,104	[redacted]	[redacted]
Natural gas	85,581	85,624	[redacted]	[redacted]
Petroleum	65,433	65,466	[redacted]	[redacted]
VOC	16.214	16	54.376	71
CO	146.284	146.358	30.768	177
NOx	70.852	70.888	89.157	160
PM10	7.807	7.811	61.004	69
PM2.5	4.059	4.061	19.973	24
SOx	32.609	32.626	38.944	72
CH4	16.826	16.834	43.194	60
N2O	40.366	40.386	1.030	41
CO2	14,567	14,574	29,032	43,606
GHG Emissions		27,030	30,419	57,449

Total Direct Emissions	54.45	g CO2/MJ EtOH
Land Use Change	30	g CO2/MJ EtOH
Denaturant (CARBOB blended at 2% with anhydrous EtOH)	0.8	g CO2/MJ EtOH
Total Carbon Intensity	**85.25**	**g CO2/MJ EtOH**

Appendix A

Columbus, NE – Dry Mill Air Permit

Appendix B

Columbus, NE – Cogen Air Permit

Appendix C

CA-GREET Electronic Files

References:

(1) Demirbas, Ayhan. 2005. New Opportunities Resulting from Cogeneration Systems Based on Biomass Gasification. Energy Sources 27, no. 10: 941-948.

(2) Industrial Technologies Program. 2004. Consider Installing High Pressure Boilers with Backpressure Turbine-Generators. Steam Tip Sheet #22. http://www.nrel.gov/docs/fy04osti/36924.pdf.