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2008 Energy Balance
for the Corn-Ethanol Industry

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Abstract

The Agricultural Resource Management Survey of corn growers for the year 2005 and the 2008 survey of dry mill ethanol plants are used to estimate the net energy balance of corn ethanol. This report measures all conventional fossil fuel energy used in the production of 1 gallon of corn ethanol. The ratio is about 2.3 BTU of ethanol for 1 BTU of energy inputs, when a portion of total energy input is allocated to byproduct and fossil fuel is used for processing energy. The ratio is somewhat higher for some firms that are partially substituting biomass energy in processing energy.

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2008 Energy Balance for the Corn-Ethanol Industry

The ratio of energy in a gallon of ethanol relative to the external fossil energy required to produce the corn and process and ship the ethanol is an important measure of sustainability of the corn-ethanol industry (Pimentel). Recent updates of energy balance calculations have verified enhanced industry performance and identified methods that could yield further improvement (Shapouri, et al; Gallagher and Shapouri). The 2008 updates presented in this report record the effects of current practices used by corn producers and ethanol processors. Current fertilizer practices are taken into account using recent data collected by the USDA. The current standards of electrical and processing energy use in the corn-ethanol industry are taken from a recent survey of ethanol producers.

Energy Consumption by Corn Producers

Corn producers use most energy products (gasoline, diesel, natural gas, liquid petroleum gas, and electricity) directly in planting, harvesting, and drying their crop. There is also considerable energy embodied in the commercial fertilizers applied to enhance plant growth.

Table 1 and Table 2 provide a summary of new USDA data on energy components and totals. The trends for components and total energy are summarized with data at 5-year intervals over the last 25 years. Agricultural Resource Management Survey (ARMS) is the source of data used to estimate total direct and indirect energy inputs used in production of corn. Energy inputs used in production of corn are derived from the responses of 1,814 corn farmers in 19 States to a survey on corn production practices and costs as part of the 2005 ARMS. The target population for the corn survey was farmers who planted corn with the intention of harvesting corn for grain. The USDA National Agricultural Statistics Service (NASS) and the Economic Research Service collect production and cost data once every 5-8 years for each commodity on a rotating basis in the ARMS. The State data from the survey are also weighted to represent all U.S. corn acreage (see Appendix Tables A1 and A2).

Importantly, the largest energy components for corn production are nitrogen and direct energy for fuel and electricity. Nitrogen use measured on a per bushel basis has declined by about 20 percent since the mid-90s. Similarly, all direct energy components have declined by about 50 percent since the mid-90s. Together, the nitrogen and direct energy reductions result in a 30 percent decline in the energy required to produce a bushel of corn. Overall, 65,285 BTU/bu (British thermal unit per bushel) were required for corn production in 1996, whereas 41,029 BTU/bu were required in 2005.

Lastly, it is the energy in corn that is actually used for ethanol production, expressed per gallon of ethanol, which is important for an evaluation of ethanol production. Ethanol yields have increased by about 10 percent in the last 20 years, so proportionately less corn is required—14,866 BTU/gal in 2005 (see Table 2). Further, only the starch fraction of the corn plant (66 percent) is used for ethanol production.[1] So the net corn energy used for ethanol production is 9,811 BTU/gal in Table 2. The corn energy required for ethanol production is shown in the bottom two rows of Table 2. The corn energy input to ethanol production declined to 9,811 BTU/gal from 16,346 over the most recent 10-year period.

[1] To see this, notice that a bushel of corn weighs 56 lbs, and yields 17.5 lbs of distilled grains (the protein, fiber and oil components of the corn plant). The starch component is 38.5 lbs = 56-17.5, so the starch fraction of the corn plant is 38.5/56 = .688, that is, the starch (ethanol-making) component is about 2/3 of the corn. In many cases the 2/3 allocation rule is very conservative – in some plants, the corn oil is removed from the distilled grain and used for biodiesel processing (a contribution to energy output).

2008 Ethanol Producer Survey

A short survey of ethanol producers in Iowa, Minnesota, Nebraska, and eastern South Dakota was conducted in the fall of 2008 and the winter of 2009. This survey was conducted by the students from the National Agricultural Marketing Association Chapters of Iowa, Minnesota, and Nebraska. The survey was designed by staff at USDA and Iowa State University. The survey included questions about the extent of thermal and electric energy use, the type of energy used, the type of ethanol production process used, and processing yield (the Survey Questionnaire is given in the Appendix). Sixteen plants responded to the survey, which is marginally enough to discuss the results.[2]

We report only survey summary measures, to accommodate the confidentiality of individual firms. Some of the data are summarized with means, group means, and standard deviations. Other results are more conveniently expressed using regressions.

First, the ethanol processing yield of survey respondents has a mean of 2.76 gal/bu of corn. Further, the standard deviation is 0.07 gal/bu. Hence, processing yields continue a slow but steady improvement—the 2009 average yield is 3.7 percent higher than the average for the 2002 USDA survey, and 4.7 percent higher than the 1998 survey.

Second, the survey responses on external thermal energy showed that several firms were using between 10 percent and 50 percent biomass power. Hence, we summarize the thermal energy results using the following regression:

$$btu_i = \underset{(23.8)}{22953}\ ddm_i + \underset{(29.4)}{29421}\ ddd_i + \underset{(28.3)}{28313}\ dw_i - \underset{(6.1)}{26920}\ fb_i$$

Adj. R^2 = .98 Dep. Var. Mean = 24840 rmse = 2973 CV = 12.0%

Numbers in parentheses are t-values

Where:
btu_i = thermal energy used, in BTU/gal
ddm_i = 1 for dry mills selling modified distiller's grains (dg), and 0 otherwise
ddd_i = 1 for dry mills selling dry dg, and 0 otherwise
dw_i = 1 for wet mills, and 0 otherwise
fb_i = the fraction of thermal energy from biomass, 0/1
i indicates data for firm i

Twenty-two observations were used for the process energy regression, because some firms that produce dry and modified dg reported energy use for both configurations.

The regression coefficient for each dummy variable indicates the average energy use of a specific processing configuration when the biomass fraction is zero. Also, a 50-percent biomass fraction would reduce the energy use of a dry mill with dry instead of wet dg by about half—a very sensible result.

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[2] The standard deviation (SD) of the sample mean ($\sigma_{\bar{x}}$) is related to the population S.D. (σ) and sample size (n) as follows: $\sigma_{\bar{x}} = \sigma / \sqrt{n}$. With the conventional sample, n=30, $\sigma_{\bar{x}} = 0.18\sigma$. A sample with n = 16 is almost as accurate: $\sigma_{\bar{x}} = 0.25\sigma$. For the farm sample, n = 1,814, sampling error of the mean is virtually eliminated, i.e., $\sigma_{\bar{x}} = 0.023\sigma$.

The thermal energy regression estimate also can be used to infer the heat increment associated with producing dry dg versus wet dg, even though results are only estimated for modified and dry dg. First, the additional thermal energy required to process dry dg instead of modified dg is the difference between the coefficients for ddd and ddm: 6,468 BTU/gal. Second, modified dg consists of a 50:50 mix of wet and dry dg. So the heat required to dry dg is 6,485/0.5 = 12,936 BTU/gal, which amounts to 44 percent of the energy required for ethanol production with dry dg with typical moisture standards.

For comparison, the USDA process model of a dry mill, the USDA-Agricultural Research Service Eastern Regional Research Center "corn dry mill process and cost model" (Kwiatkowski, et al.), suggests a similar but slightly higher estimate. They calculate that 51 percent of the thermal energy used in an ethanol plant is attributable to producing dry dg with 10 percent moisture content. In subsequent calculations of the byproduct credit in corn-energy balance, we examine the survey estimate and the process model estimate.

Third, the survey responses also suggest that electricity use is related to the fraction of dg that is dried:

$$elec_i = \underset{(9.1)}{0.60214} + \underset{(1.5)}{0.15476}\, fd_i$$

Adj. R^2 = .095   Dep. Var. Mean = 0.6858   rmse = 0.1311   CV = 19.2%

Where
$elec_i$ = electricity use, in kWhr/gal
fd_i = fraction of dg that is dried, 0/1

Energy Balance Estimate

Table 3 contains an update for the energy balance results given in Gallagher and Shapouri.[3] The revision includes latest data for corn energy use from the USDA survey, for ethanol conversion from the National Agribusiness Marketing Association (NAMA) survey, and transportation from the GREET model (version 1.8). A dry mill with dry distiller's grains is the reference case of Table 3. The columns report energy use with conventional fossil fuel power (Columns 1 and 2) and with biomass power (Columns 3 and 4). Finally, the byproduct credit is the heat used to prepare dry dg—we compare the regression estimate using the NAMA data (Column 2) and the engineering model estimate (Column 1).

For the conventionally powered dry mill, shown in Columns 1 and 2, the ethanol conversion estimate of heat content, 40,019 BTU/gal, is the sum of electricity and thermal energy from the NAMA regression estimates, appropriately configured. Additionally, survey reported numbers are all adjusted to an energy input basis. The corn production estimate is also the same, at 9,811 BTU/gal from the 2005 USDA data given in Table 2. The byproduct credit in Column 1 of 20,409 BTU/gal is based on the ASPEN model. But the Column 2 estimate of byproduct credit is inferred from the regression estimate. The various components of energy use are compared to the heat content of ethanol (76,300 BTU/gal). Together, the recent energy use estimates show that the ratio of energy in ethanol to the external energy used to produce ethanol is about 1.4, even without allowing for the processing component of the byproduct credit. After fully allowing for heat used to produce byproducts, the energy ratio is between 1.9 and 2.3.

[3] Our analysis updates the energy balance picture for a representative firm, using methods developed previously. At the market level, we assume that the representative firm is not part of an industry expansion that is large enough to displace land from previous uses.

Biomass power reduces the external fossil energy needed to produce ethanol. In the case of corn stover, some of the fossil energy used to produce corn-biomass is recovered. Energy required for stover harvest and fertilizer replacement is taken into account in Column 3. In a typical dry mill, biomass power would replace natural gas, but market purchases of electricity would likely continue. At the upper range of survey responses shown in Column 3, external thermal energy reduces by about one-half, to 15,961 (BTU = 29421-26920 * 0.5) BTU/gal on an output basis, and external energy for electricity would remain at 8,720 BTU/gal. Under these circumstances, the energy balance ratio increases to 2.8, even using the lower byproduct credit from the regression results. Similar calculations that used a short rotation woody crop (willow) instead of stover yielded similar energy balance estimates.

In Column 4, complete replacement of external processing energy for thermal energy and electricity extends beyond the range of survey responses. But the possibilities are interesting. Corn residues, which contain about the same energy (BTUs) as the corn, are presently discarded. But residues represent enough energy to replace all of the process heat and electricity needed for ethanol, and combined heat and power plants are capable of producing the required process heat and electricity. Hence, the energy balance could increase to about 25.7 when half of the renewable energy produced in corn production (the residue) is no longer discarded.

Conclusion

A dry grind ethanol plant that produces and sells dry distiller's grains and uses conventional fossil fuel power for thermal energy and electricity produces nearly two times more energy in the form of ethanol delivered to customers than it uses for corn, processing, and transportation. The ratio is about 2.3 BTU of ethanol for 1 BTU of energy in inputs, when a more generous means of removing byproduct energy is employed.

Some dry mills are already using up to 50 percent biomass power. The energy output for these plants is near 2.8 times energy inputs, even using the conservative byproduct allowance. As processors master the logistics of handling bulky biomass, the energy balance ratio could reach 26 BTUs of ethanol per BTU of inputs used.

Overall then, ethanol has made the transition from an energy sink, to a moderate net energy gain in the 1990s, to a substantial net energy gain in the present. And there are still prospects for improvement.

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Tables

Table 1. Energy-related inputs used to grow corn, nine-State weighted average | **Energy Used** | **Table 2. Total energy requirements of farm inputs for nine-State average**

		1991	1996	2001	2005	Conversion factors: [a] Energy inputs to BTU		in BTU/bu corn:	1991	1996	2001	2005
Seed [c]	Pounds/acre	19.62	19.61	22.11	18.29	394.26	BTU/pound		784	860	663	394
Fertilizer:												
Nitrogen	Pounds/acre	124.5	129.38	133.52	133.39	24,500	BTU/pound		25,023	25,358	23,477	20,464
Potash	Pounds/acre	52.77	59.25	88.52	61.26	3,000	BTU/pound		1,299	1,422	1,899	1,151
Phosphate	Pounds/acre	58.17	48.16	56.81	54.36	4,000	BTU/pound		1,909	1,541	1,631	1,362
Lime [b]	Pounds/acre	242.18	382.18	350	554.36	558	BTU/pound		1,109	1,706	1,402	1,937
Energy Input:												
Diesel	Gallons/acre	6.85	8.6	6.85	5.81	152,372	BTU/gallon		8,562	10,483	7,491	5,539
Gasoline	Gallons/acre	3.4	3.09	1.7	1.92	144,211	BTU/gallon		4,022	3,565	1,759	1,735
LPG	Gallons/acre	3.42	6.36	3.42	3.2	85,895	BTU/gallon		2,410	4,370	2,108	1,722
Natural gas	Cubic ft/acre	246	200	245.97	208.9	1,046	BTU/ft^3		2,111	1,674	1,846	1,368
Electricity	kWh/acre	33.59	77.13	33.59	20.41	9,365	BTU/kWh		2,581	5,779	2,258	1,197
Custom work	Dollars/acre	6.68	15.07	10.12	8.45				1,590	3,340	1,581	648
Chemicals	Pounds/acre	3.99	3.49	2.66	2	154,150	BTU/pound		5,049	4,304	2,941	1,928
Custom drying	Dollars/acre	1.79		0	2.09				1,030	0	0	642
Purchased water	Dollars/acre			0.18	0.08						136	75
								Total:	58,095	65,285	49,819	41,029
Yield, 3-year average bu/acre		121.9	125	139.34	159.7							

[a]Includes energy loss and transmission loss (LHV)
[b] Lime use in 1996 is an average of 1991, 2001, and 2005
[c] Seed conversions calculation shown below:

	1991	1996	2001	2005
seeds per acre	25,501	25,495	28,739	23,771
pounds of seed/acre	19.62	19.61	22.11	18.29
bu seed/bu corn	0.0029	0.0028	0.0028	0.002
BTU/bu corn seed	166.94	182.91	141.14	83.89
magnification factor	4.7	4.7	4.7	4.7
BTU/bu corn, adjusted	784	859	663	394

conversion to BTU/gallon ethanol:

	1991	1996	2001	2005
BTU/bu	58,095	65,285	49,819	41,029
gal/bu	2.50	2.64	2.66	2.76
BTU/gal	23,238	24,767	18,715	14,866
starch fraction	0.66	0.66	0.66	0.66
ethanol's share (BTU/gal)	15,337	16,346	12,352	9,811

Abbreviations: DDG: dry distillers grains; NG: natural gas; GREET: Greenhouse Gasses, Regulated Emissions, and Energy Use is Transportation Model; SRWC: short rotation woody crops, and LPG: liquefied petroleum gas.

Table 3 Corn Ethanol Dry Mill producing dry distillers grains (ddgs): Energy use and net energy value

Processing Power Configuration	Natural Gas & Purchased electricity		Biomass Power, Replace 50% w/Corn Stover	Biomass power, Replace 100%
	ASPEN DDG credit	Survey DDG credit	of Natural Gas (NG)	of NG & elec w/ Corn Stover
	in BTU / gallon			
Corn Production	9,811	9,811	9,811	9,811
Corn Transport	1,430	1,430	1,430	1,430
Ethanol Conversion	40,019 [1]	40,019	26,767 [4, 2]	2,135 [2]
Ethanol Distribution	1,470	1,470	1,470	1,470
Farm Machinery	1,055 [5]	1,055	1,055	1,055
Total Energy Used	53,785	53,785	40,533	15,901
Byproduct Credit	20,409 [3]	12,936	12,936	12,936
Energy Used, Net of Byproduct Credit	33,375	4,0849	27,597	2,965
Ethanol Energy Produced	76,300	7,6300	76,300	76,300
Energy Ratio, w/o Byproduct Credit	1.42	1.42		
Energy Ratio, w/ Byproduct Credit	2.29	1.87	2.76	25.73

Footnotes: (sources and calculation details)

1

	kwhr elec /gal eth	BTU elec /kwhr elec	BTU out/gal	BTU elec/BTU input	BTU out/ BTU in	BTU in /gal
Electricity:	0.757	3,413		0.30		8,720
Power:			29,421		0.94	31,299
					Total:	40,019

Source: Gallagher and Shapouri (2006)

2 corn-stover harvest energy, BTU/ gal (direct+energy embodied in machinery) from GREET model,Wang 912
Corn-stover fertilizer replacement requirement BTU/ gal from Gallagher, Dikemen, and Shapouri (2003) 1,223
Total: 2,135

3 51.0 percent of total energy used for ddg preparation. See McAloon, et al., ASPEN model.

4

	kwhr elec /gal eth	BTU elec /kwhr elec	BTU out/gal	BTU elec/BTU input	BTU out/ BTU in	BTU in /gal
Electricity:	0.757	3,413		0.30		8,720
Power:			15,961		0.94	16,980
Corn-stover harvest:						456
Corn-stover fertilizer replacement:						611
					Total:	26,767

5 energy in farm machinery (steel and tire production, assembly, repair parts): 2,913 BTU/ bu from GREET model, Wang

Table A1. Energy-related inputs used to grow corn in nine States and nine-State weighted average, 2005

		IL	IN	IA	MI	MN	NE	OH	SD	WI	Nine-State Weighted Avg.
Yield (2004-06)	*Bushels/acre*	161.8	159.61	173.34	141.4	164.61	157.34	153.09	116.77	142.55	159.70 0
Seed	*Kernels/acre*	24,180	23,660	24,700	23,010	24,700	21,710	24,050	20,540	24,960	23,771
Fertilizer:	*Pounds/acre*										
Nitrogen	*Pounds/acre*	147.51	146	128.87	119.43	129.18	130.42	161.37	107.5	101.7	133.39
Potash	*Pounds/acre*	94.19	104.91	60.64	72.55	54.85	6.59	79.05	10.73	51.1	61.26
Phosphate	*Pounds/acre*	64.68	67.84	46.87	40.19	52.66	60.06	59.31	36.48	34.8	54.36
Lime	*Pounds/acre*	836	858	714	644	112	188	722	2	676	554.36
Energy Inputs:											
Diesel	*Gallons/acre*	4.50	4.20	3.00	4.70	4.10	17.00	3.70	2.60	6.60	5.81
Gasoline	*Gallons/acre*	1.80	2.50	1.70	2.70	2.10	1.70	2.20	1.60	2.00	1.92
LPG	*Gallons/acre*	2.00	4.10	2.60	1.60	8.10	1.70	3.70	0.40	3.60	3.20
Natural gas	*Cubic ft/acre*	90.00	40.00	0.00	80.00	30.00	1,200.00	100.00	10.00	70.00	208.90
Electricity	*kWh/acre*	25.70	14.40	6.80	10.90	16.70	50.60	7.00	11.40	32.00	20.41
Custom work	*Dollars/acre*	7.09	7.05	6.81	8.69	8.99	11.87	8.05	8.78	13.38	8.45
Custom drying	*Dollars/acre*	2.18	0.20	3.34	2.60	2.98	0.25	2.10	0.24	3.90	2.09
Purchased water	*Dollars/acre*	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.08
Chemicals	*Pounds/acre*	2.47	1.71	1.75	2.22	1.71	2.27	2.85	1.34	1.60	2.00
2005 production	*1,000 bushels*	1,708,850	88,8580	2,162,500	288,860	1,191,900	1,270,500	464,750	470,050	429,200	8,875,190

Table A2. Total energy requirements of farm inputs for nine States and nine-State weighted average, 2005

	IL	IN	IA	MI	MN	NE	OH	SD	WI	Nine-State Weighted Avg.
					BTU to produce 1 bushel of corn					
Seed	412	408	300	437	355	506	469	386	474	394
Fertilizer:										
Nitrogen	22,336	22,411	18,215	20,693	19,227	20,308	25,825	22,555	17,479	20,464
Potash	1,746	1,972	1,049	1,539	1,000	126	1,549	276	1,075	1,151
Phosphate	1,599	1,700	1,082	1,137	1,280	1,527	1,550	1,250	976	1,362
Lime	2,883	3,000	2,298	2,541	380	667	2,632	10	2646	1,937
Energy Inputs:										
Diesel	4,238	4,010	2,637	5,065	3,795	16,463	3,683	3,393	7,055	5,539
Gasoline	1,604	2,259	1,414	2,754	1,840	1558	2,072	1,976	2,023	1,735
Liquefied Petroleum Gas	1,062	2,206	1,288	972	4,227	928	2,076	294	2,169	1,722
Natural gas	582	262	0	592	191	7,978	683	90	514	1,368
Electricity	1,488	845	367	722	950	3,012	428	914	2,102	1,197
Custom work	537	541	481	753	669	924	644	921	1,150	648
Custom drying	661	62	946	903	889	78	673	101	1,343	641
Purchased water	0	0	0	0	0	533	0	0	0	75
Chemicals	2,353	1,652	1,556	2,420	1,601	2,224	2,870	1,769	1,730	1,928
Input hauling	1,213	1,279	966	1,099	277	479	1,129	70	1,172	868
Total energy	42,714	42,606	32,601	41,627	36,679	57,310	46,284	34,003	41,909	41,029

Energy in custom work accounts for 16%, diesel fuel is used as source of energy
Energy in custom drying account for 80%, propane is used as source of energy
Energy in purchased water account for 90%, electricity is source of energy
Energy used for seed is 4.7 times higher than energy used for corn
Weighted average of insecticides and herbicides are used to estimate energy in pesticides
Energy used to haul input to farm is equal to weight of lime, diesel fuel, gasoline, LPG and pesticides multiplied by 218.5 BTU per pound

Appendix: Survey Forms

2008 NAMA Ethanol Producer Energy Use Survey

This survey asks for your use of energy during the course of producing ethanol. The information you provide will be used to calculate an industry average "benchmark" of the ethanol industry's energy balance ratio. In this fashion, any improvement in the ethanol industry's performance as a biofuel can be documented. The current benchmark is also useful to individual firms because they can identify areas of potential improvement.

This survey also asks a few optional questions about a few cost components that change over time with changing technology. The questions focus on a few components of operating cost and plant construction expenditures—overall production cost is not requested.

If you are currently an ethanol producer, please fill out the questionnaire and return it to the on-site interviewer. Otherwise, return the completed questionnaire in the enclosed envelope. Every individual's response will remain confidential. But statistical summary measures will be used for analysis of the industry and made available to the public.

All of the questions ask for energy use or cost on a "per gallon of non-denatured ethanol basis."

About NAMA

The National Agribusiness Marketing Association (NAMA) provides professional development activities for university students majoring in Agribusiness. NAMA chapters at the University of Minnesota, University of Nebraska, and Iowa State University are conducting the survey.

<u>Questions for Dry Mill Producers</u>:

Section A – Ethanol producer's energy use

The net energy balance of ethanol producers depends on a few critical energy use parameters. A separate list of questions is given below for dry mill producers and for wet mill producers.

1d. What is your yield of ethanol produced per bushel of corn processed?
(in gallons of non-denatured ethanol/bushel of corn)

2d. What is your thermal energy used in the production of ethanol and *dry* dg?
(in BTU/gallon of ethanol)

3d. What is your thermal energy used in the production of ethanol and *modified (not dried)* dg?
(in BTU/gallon of ethanol)

4d. How much electricity is used in the production of ethanol and dry dg?
(in kWh/gallon of ethanol)

5d. What percent of your distiller's grain is sold as wet_____, modified_____, or dry____?
(in percent, 1% to 100%)

6d. What is the source of your thermal energy for steam production?
natural gas_____ coal_____ biomass_____
(check with X, or provide percentages if more than one applies)

7d. How much corn did you process last year?______
(in million bushels)

Section B – Optional Cost Survey. Answers should be in $/gallon of non-denatured ethanol.

1. What are your operating costs, in total (in $/gallon ethanol)?
Note: operating costs typically include electricity, fuel, waste management, water, enzymes, yeast, chemicals, denaturant, labor, administrative costs, and labor

2. What are your electricity costs (in $/gallon ethanol)?

3. What are your fuel costs (in $/gallon ethanol)?

4. What are your labor costs, excluding administrative costs (in $/gallon ethanol)?

5. What initial expenditure did you incur building your plant (in $)?

6. What is your plant capacity (in million gallons of ethanol/year)?

7. When was your plant built (e.g., in 2003)?

<u>Questions for Wet Mill Producers:</u>

Section A – Ethanol Producer's Energy

1w. What is your yield of ethanol produced per bushel of corn processed?
(in gallons of non-denatured ethanol/bushel of corn)

2w. What is your thermal energy used in the production of ethanol and byproducts (gluten feed, gluten meal, and corn oil)?
(in BTU/gallon of ethanol)

3w. How much electricity do you purchase from the grid (in kWh/gallon of ethanol)?

4w. What is the source of your thermal energy for steam production?
natural gas_____ coal_____ biomass_____ other _____
(check with X, or provide percentages if more than one applies)

5w. How much corn did you process last year?______
(in million bushels)

Section B – Optional Cost Survey. Answers should be in $/gallon of non-denatured ethanol.

1. What are your operating costs, in total (in $/gallon ethanol)?
Note: operating costs typically include electricity, fuel, waste management, water, enzymes, yeast, chemicals, denaturant, labor, administrative costs, and labor

2. What are your electricity costs (in $/gallon ethanol)?

3. What are your fuel costs (in $/gallon ethanol)?

4. What are your labor costs, excluding administrative costs (in $/gallon ethanol)?

5. What initial expenditure did you incur building your plant (in $)?

6. What is your plant capacity (in million gallons of ethanol/year)?

7. When was your plant built (e.g., in 2003)?